WATLOW

Optimizing Your Process System with the Series 988 Controller

An Application Guide for the Watlow Series 988 Family

Watlow Mission Statement

To Become the Preferred Source of Industrial Heaters, Sensors and Controls by Totally Satisfying Our Customers with Superior Products, Quick Delivery on Specials, as well as Standards, and Intelligent Sales Support.

Introduction

Welcome to the Watlow Series 988 application guide: *Optimizing Your Process System with the WATLOW Series 988.* This application guide describes all the features of the Series 988 and how they can be applied to your system. In addition, this guide will walk you through the process of determining the optimal Series 988 for your application. Once you have purchased the controller, the *Series 988 Users Manual* will guide you through installation and setup of the controller.

Start with Chapter One of this book, where “test drives” show the thought process used for determining the correct Series 988 feature set for a specific application. Chapter Two consists of a glossary and a question-and-answer section that provides more details to help choose the right control. Chapters Three through Five describe the features of the controller with a sample application for each feature. Chapter Six outlines the controllers’ specifications. Use this chapter to ensure that the controller interfaces correctly with other system components. Finally, Chapter Seven walks you through the feature set selection for your specific application. Once you have used the guide a few times, you will be able to skip to Chapter Seven and use the previous chapters for reference.

The purpose of this technical guide is to assist you in the system design process. The final responsibility for the system design must remain with the system design engineer.

Watlow manufactures heaters, sensors and controls. We can provide a complete thermal system. For more information concerning the Series 988, contact your local sales representative listed on the back cover. Literature on the Series 988 includes:

- *Series 988/989 Users Manual*
- *Calibrating Watlow Process Controls*
- *How to Use Data Communications with the Watlow Series 988/989* or *How to Use Data Communications with the Watlow Process Controls*

Disclaimer of Warranty

The information presented here is of a general nature. Because of the diversity of conditions and hazards under which control products may be applied and because of the differences in components and methods of installation, <u>no representation or warranty of any kind, express or implied, is hereby made</u>, that the applications discussed herein will be effective in any particular application or set of circumstances, or that additional or different precautions will not be reasonably necessary for a particular application.

We will be pleased to consult with you regarding a specific application, upon request.

Table of Contents

Watlow Mission

Introduction

Chapter 1 **Test Drives**		1.1
	Controlling an Extruder	1.2
	Drying Grain	1.4
	Melting Aluminum	1.6
	Mixing Urethane	1.8
Chapter 2 **Basic Control Strategies and Terms**		2.1
	Glossary	2.2
	Questions and Answers	2.5
	Control Strategies	2.8
Chapter 3 **General Software Features**		3.1
	Auto-tune	3.2
	Burst fire	3.3
	Communications	3.4
	Dead band	3.5
	Digital event	3.6
	Heater current	3.7
	Input filter	3.8
	Input linearization	3.9
	Ramp to set point	3.10
	Remote set point	3.11
	Retransmit (master/remote)	3.12
	Slidewire feedback	3.13
Chapter 4 **Enhanced Software Features**		4.1
	Cascade	4.2
	Differential	4.4
	Dual PID sets	4.5
	Duplex	4.6
	Ratio	4.7

Chapter 5 **Standard Features** 5.1

Alarms	5.2
Auto/Manual	5.4
Diagnostics	5.5
Input errors	5.6
Lockout	5.7
Transmitter power supply	5.8

Chapter 6 **Specifications** 6.1

Input Table	6.2
Output Table	6.3
Dimensions	6.4
Displays and Keys Chart	6.5
Setup Requirements	6.6
User's Manual	6.7
Product Specifications	6.8
Warranty	6.9

Chapter 7 **Select the 988 That Fits Your Application** 7.1

Overview	7.2
Input	7.3
Output	7.4
Software	7.5
Standard Features	7.6
Hardware	7.7
Review and Optimize	7.8
Application Worksheet	7.10
Series 988 Model Number Worksheet	7.11

Index 8.1

Prompts, parameters and menus	8.4

Watlow Sales Offices back cover

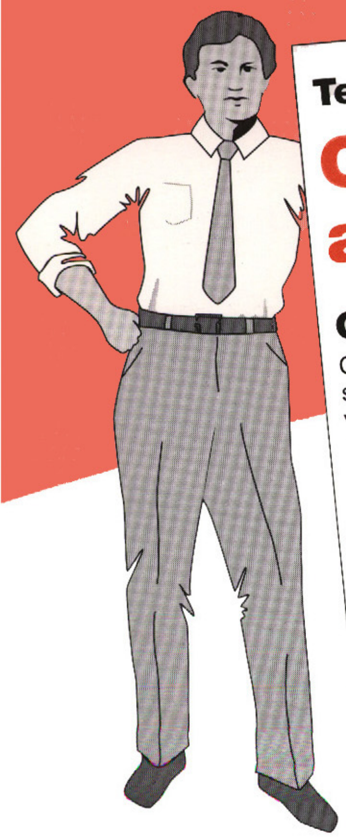
Chapter One

Test Drives

Controlling an Extruder	1.2
Drying Grain	1.4
Melting Aluminum	1.6
Mixing Urethane	1.8

How to use this chapter:

This chapter describes four actual applications in which processes are optimized by using Watlow Series 988 controllers.



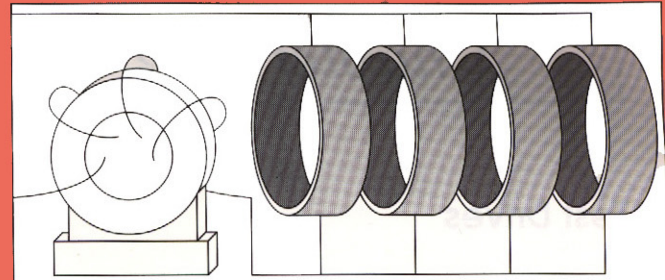
Test Drive:

Controlling an Extruder

Overview:

Chris, an engineer for Acme Extruders, studied the products of several vendors to find a control for several extruders that could:

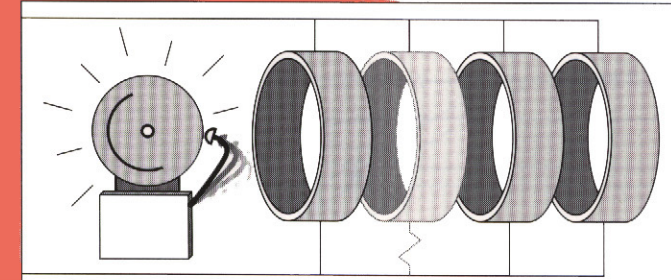
- detect heater burnout, to minimize down time and improve quality;
- easily run a variety of materials requiring different tuning parameters;
- prevent machine operators from changing parameters;
- maintain tight control of process quality;
- be automatically tuned to minimize set-up time.



The heater current input can detect the failure of a heater or the power control device.

Inputs:

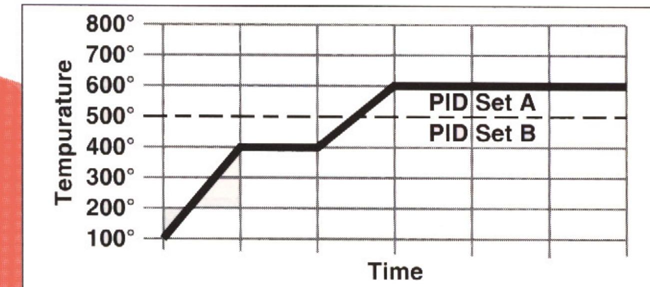
Detecting a burned out heater required an input that monitors heater current and turns ON an alarm if a heater fails. In extruders it is not always apparent that a heater has failed because adjacent zones may make up for it. The machine continues running, but results in a slow start up and inconsistent product. Chris decided to attach a J thermocouple and a current detector to inputs 1 and 2.



Chris needed a control that could alert the operator if a heater burned out.

Outputs:

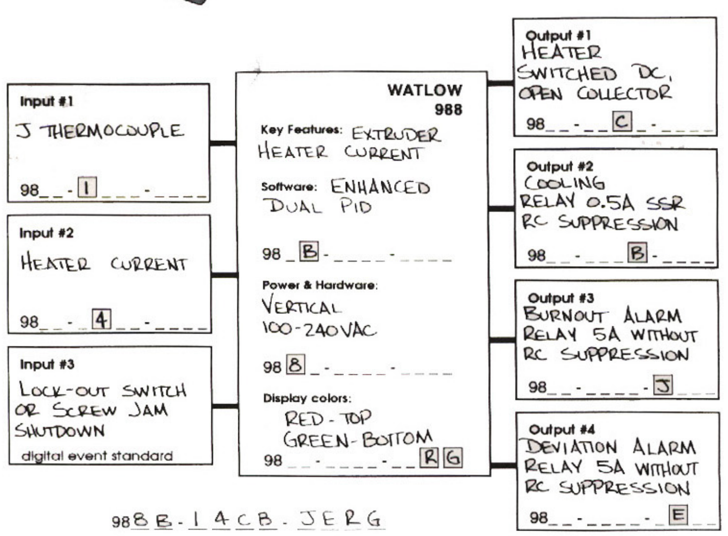
The engineer decided to use a solid-state relay to control the heaters, allowing short cycle times and optimal control. Solid-state relays were chosen for the secondary (cooling) output to control a solenoid valve for cooling water. Two mechanical relay alarms were added: one tagged to the heater current input to alert the operator of a heater burn out and the second to alert the operator if the process deviated too far from the set point.

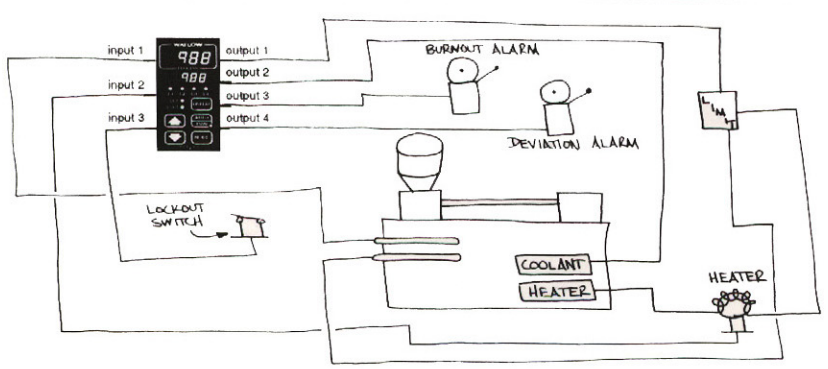


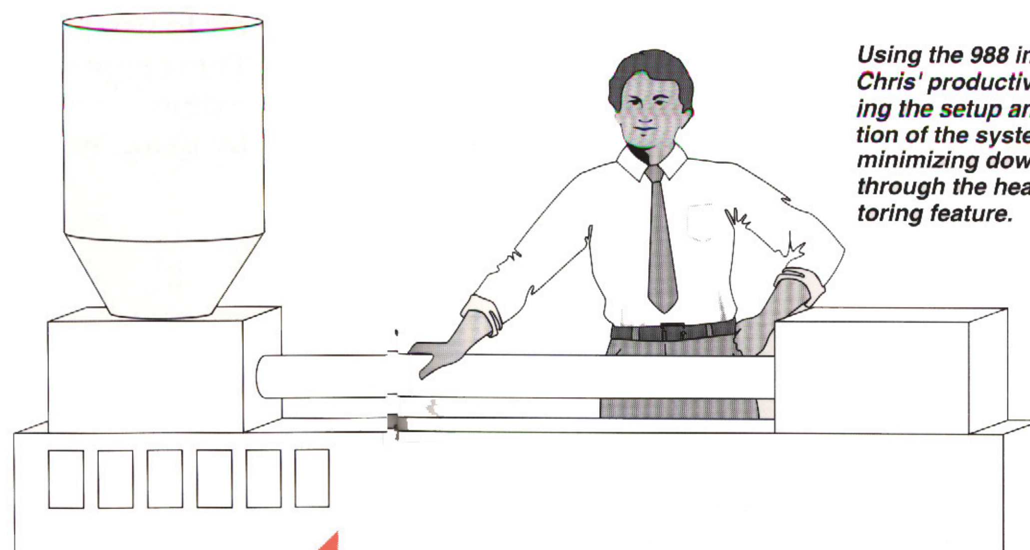
Chris ran the extruder at different temperatures requiring separate PID parameters. The dual PID option allows the selection to be made automatically.

Software:

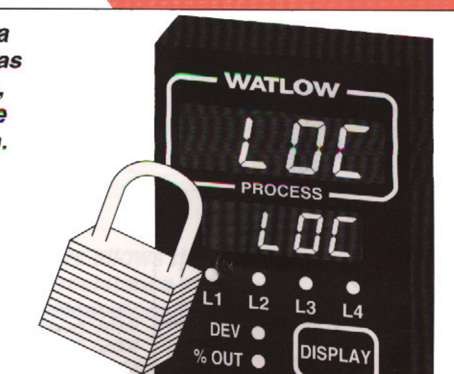
Chris decided to use two sets of PID parameters to allow the control to automatically select between the two sets, based on the set point. This allowed optimal control over a wide range of temperatures. Dual PID requires the 988 to have enhanced software.







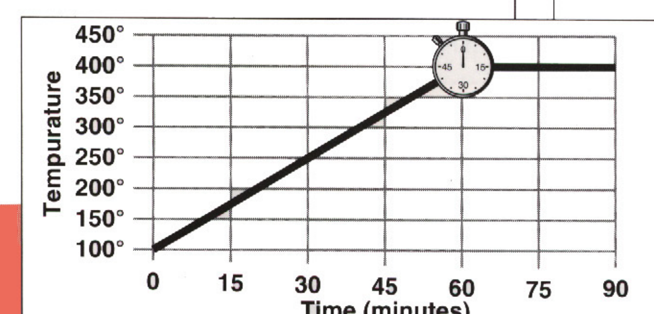
Using the 988 improved Chris' productivity by easing the setup and operation of the system and by minimizing down time through the heater monitoring feature.



Chris wanted a control that was easy to set up, yet couldn't be tampered with.

Standard Features:

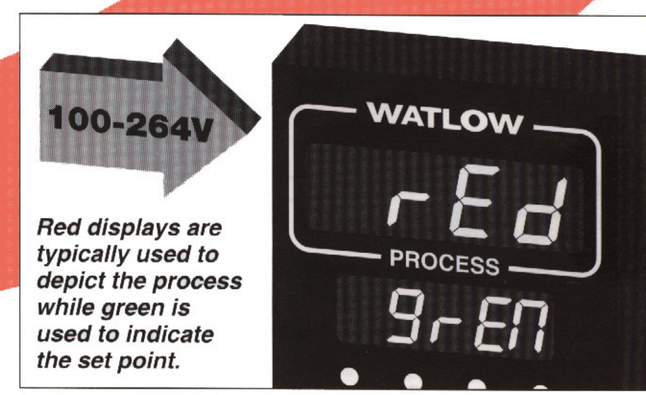
The standard auto-tune feature allowed the operator to quickly set up the heat and cool parameters. The standard lockout feature would prevent anyone but the authorized operator from changing the settings.



Chris programmed a 5° per min. heat-up rate on start-up to bring the process up to set point over a 1-hour period.

Review and Optimize:

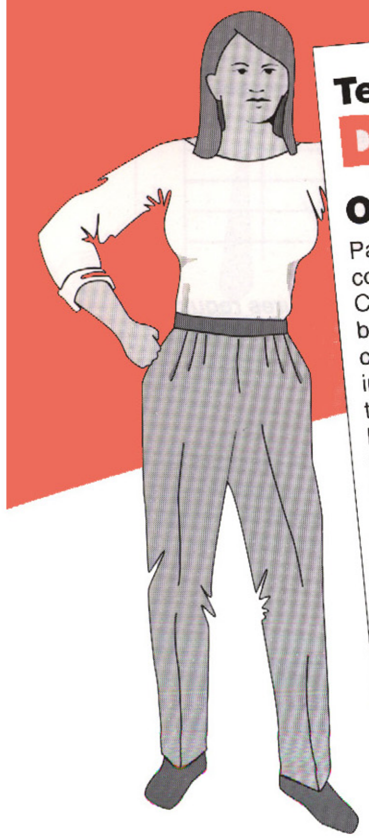
After reviewing the application Chris decided to use the event input to shut down the process if the extruder screw jammed. The conscientious engineer also added the ramp-to-set-point feature to reduce stress on the machine as it heats up.



Red displays are typically used to depict the process while green is used to indicate the set point.

Hardware:

Chris chose the vertical control with the high voltage (100-264V) option and picked a red upper display and a green lower display to make it easier for operators to visualize the process.



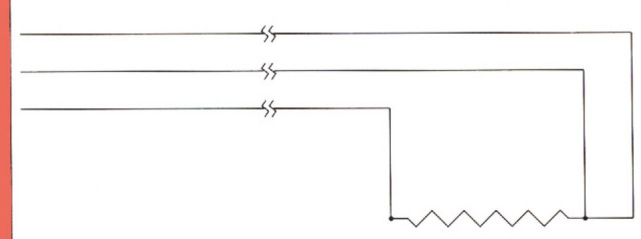
Test Drive: Drying Grain

Overview:

Pat, an engineer for Grain Inc., was considering replacing a failed Barber Coleman 560 control and an external board used for slidewire control. The control had regulated air temperature in a grain dryer by adjusting the position, via slidewire feedback, of a large louver that controlled the amount of air flowing across the grain. The temperature of the grain was measured with a 100Ω, platinum, three-wire RTD.

She was especially concerned about four factors:

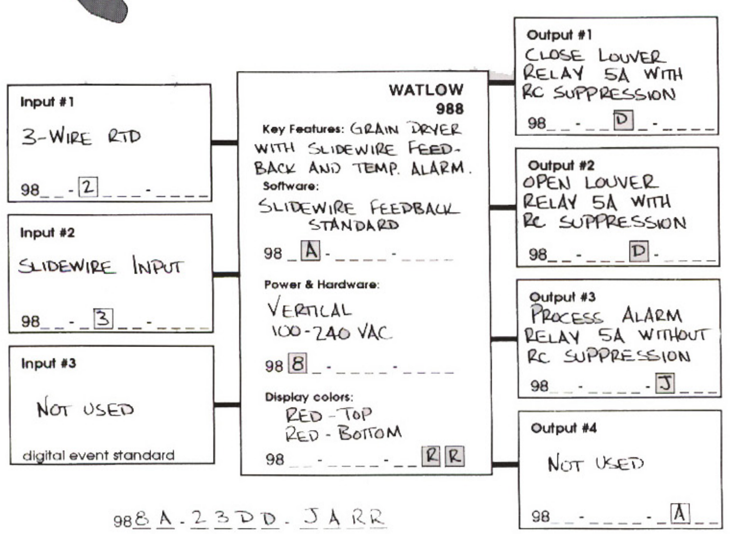
- the cost of repair versus replacement with the Series 988;
- display of the actual louver position and manual control of the louver;
- simplifying the system and making it easier to maintain;
- system setup time.

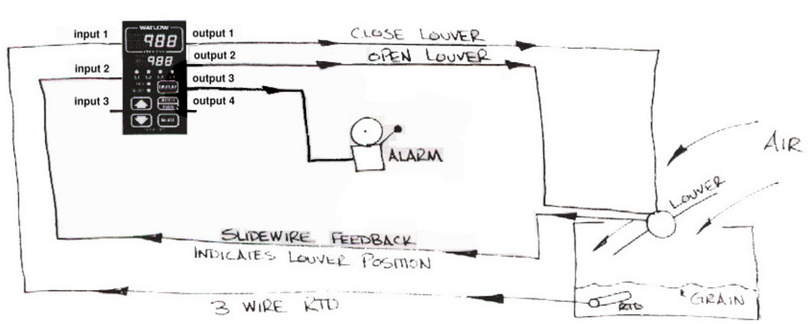


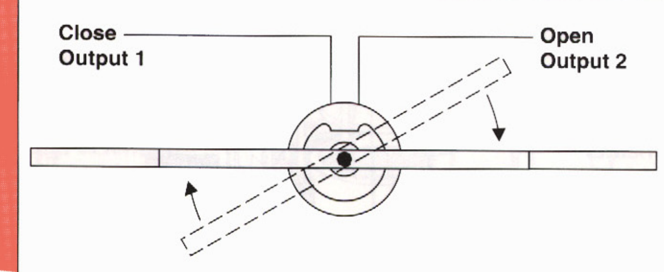
A three-wire RTD was chosen for accuracy at near ambient conditions. Also, due to the long lead length, a three-wire RTD was used to prevent inaccuracies due to lead wire resistance.

1. Inputs:

Pat needed to directly replace the Barber Coleman control and contacted the factory for a cross reference. The factory recommended a Series 988 with a universal input as the primary input (input 1) and a slidewire feedback input as input 2. The universal input accepts a 100Ω RTD and the slidewire impedance was 1000 ohms, within the specifications of the 988's slidewire input.



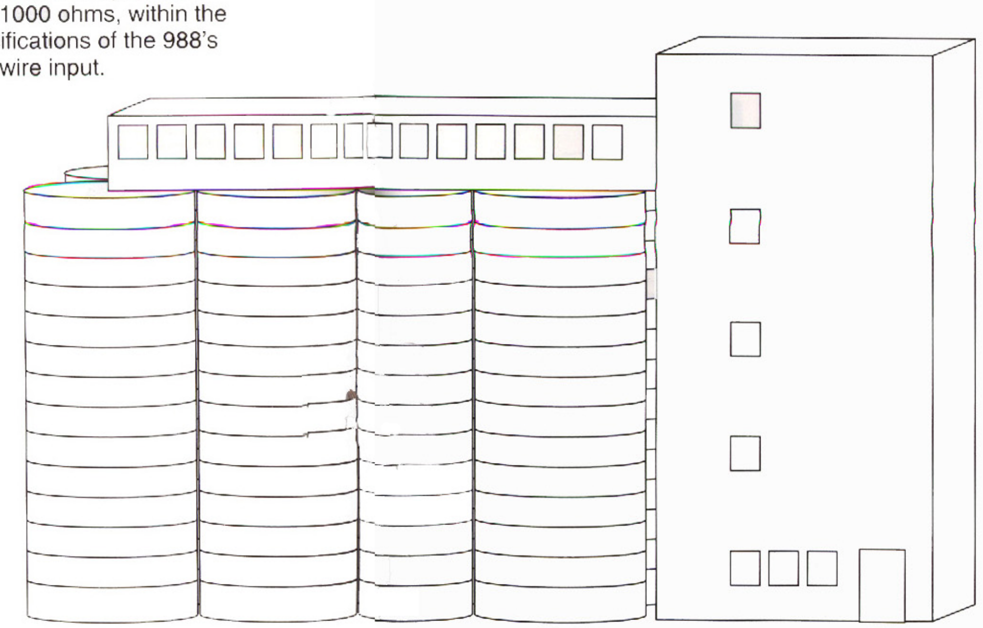


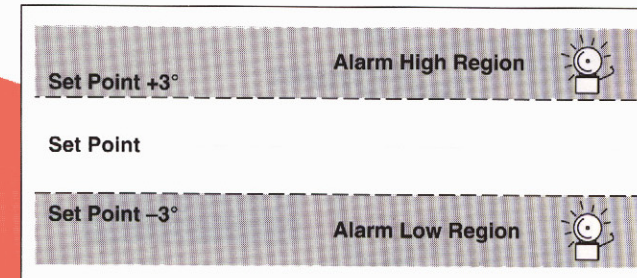


A reversible motor controls the louver position.

2. Outputs:

The slidewire option requires two electromechanical relay outputs to drive the louver positioning motor. One output opens the louver and another output closes the louver.

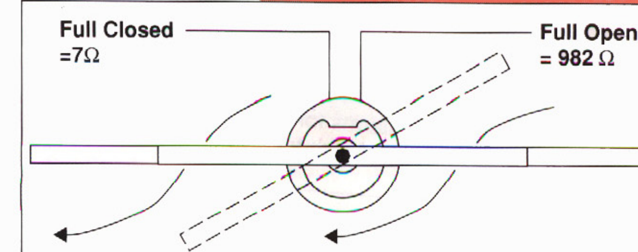




The alarm indicates that the temperature has deviated from the set point by more than 3°.

3. Software:

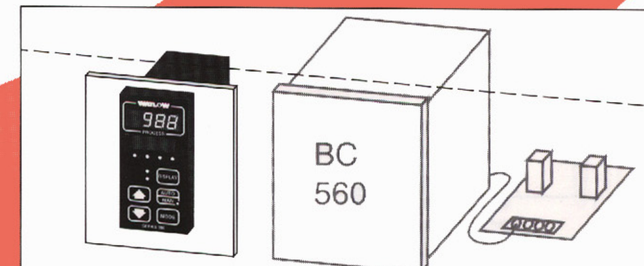
The slidewire feature does not require the Series 988 enhanced software option. Pat decided to add an electromechanical relay alarm to output 3, to indicate if the temperature of the grain deviated from the set point by more than three degrees.



The slidewire feature allows the controller to easily learn the resistance at the full-open and full-closed position.

4. Standard Features:

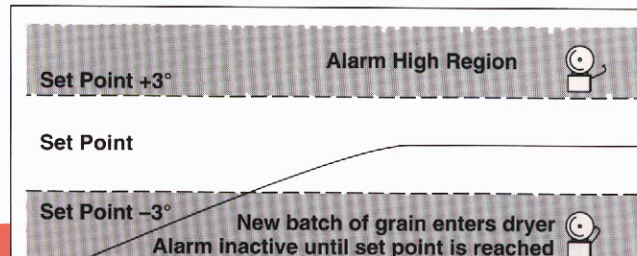
Several standard features impressed Pat. She liked the ability to calibrate the slide-wire input from the front of the control. The anti-hunting feature allowed the operator to configure a deadband for the louver position that prevented unwanted hunting by the louver control motors. Also, the ability to monitor and manually control the louver position was a plus.



The much smaller Watlow 988 controller replaced the half-DIN Barber Coleman and external board, greatly reducing the space and wiring requirements.

5. Hardware:

The control required operation at 120VAC, and the operator chose red upper and lower displays to match the other controls in the panel. The electrician who installed the control greatly appreciated the touch-safe terminals on the back of the 988.



The silencing feature would keep the alarm from being activated until a new bed of grain warmed up to the set point temperature.

6. Review and Optimize:

The operator chose I/O, software and hardware needs for the application that will provide for all her needs. Once the control is installed the system could be further optimized by using the event input to lockout the front panel, or the alarm silencing feature could be set to silence the alarm when a new bed of grain is brought in at a temperature much lower than the set point. The system costs were comparable to the cost of servicing the Barber Coleman control.

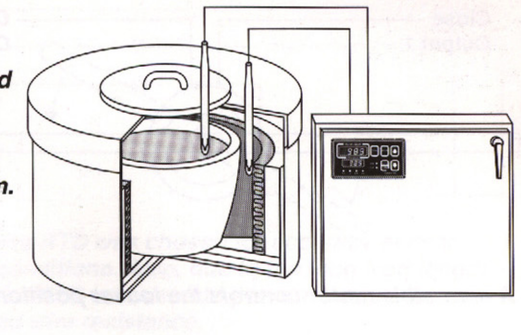
Test Drive: Cascade Control of an Aluminum Melting Furnace

Overview:

Andy is responsible for an aluminum melting furnace at Ajax Castings. The heaters on an aluminum melting furnace must run at near capacity for extended periods. To maximize heater life, temperature of the face of the ceramic fiber heater must be tightly controlled. He needed a controller with:

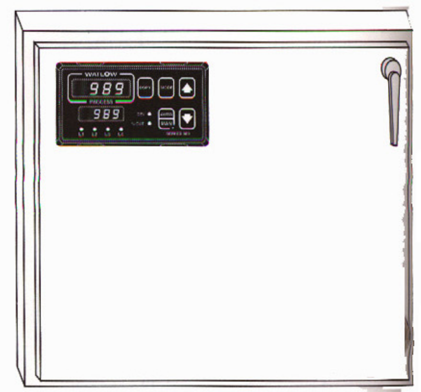
- burst-fire control;
- PID control of both heater and aluminum;
- dual inputs for measuring heater and aluminum;
- alarms for both low and high temperatures.

Type K thermocouples monitored both the heater face and aluminum.



Inputs:

With a melting point of 1080 degrees F and an expected heater temperature of 1800 degrees, Andy chose K type thermocouples for measuring both the heater face and the aluminum.



Input #1 ALUMINUM TYPE K THERMO-COUPLE
98_ _-[1]_ _ _-_ _ _ _

Input #2 HEATERFACE TYPE K THERMO-COUPLE
98_ _-_[1]_ _-_ _ _ _

Input #3
NONE
digital event standard

WATLOW 988

Key Features: ALUMINUM FURNACE WITH BURST FIRE AND 2 THERMOCOUPLE INPUTS.

Software:
CASCADE REQUIRES ENHANCED SOFTWARE
98_[B]-_ _ _ _-_ _ _ _

Power & Hardware:
HORIZONTAL CONTROLLER 100-240 VAC
98[9]_-_ _ _ _-_ _ _ _

Display colors:
RED UPPER AND LOWER
98_ _-_ _ _ _-_ _[R][R]

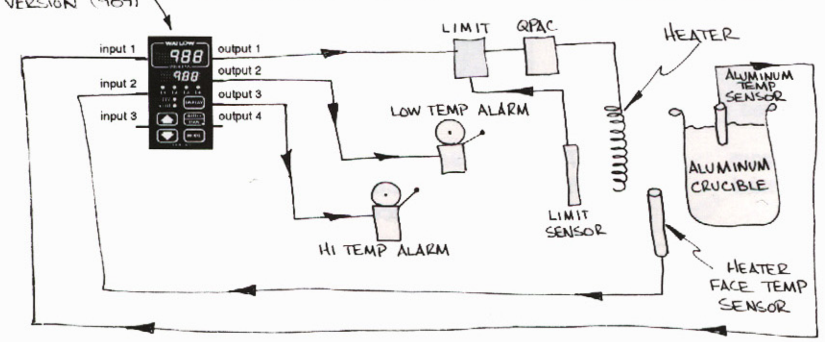
Output #1
BURST FIRE HEATER OPEN COLLECTOR
98_ _-_ _[C]_-_ _ _ _

Output #2
LOW TEMP ALARM RELAY 5A WITHOUT RC SUPPRESSION
98_ _-_ _ _[D]-_ _ _ _

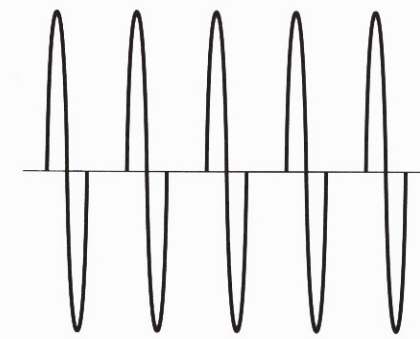
Output #3
HIGH TEMP ALARM RELAY 5A WITHOUT RC SUPPRESSION
98_ _-_ _ _ _-[J]_ _ _

Output #4
NONE
98_ _-_ _ _ _-_[A]_ _

USE HORIZONTAL VERSION (989)
989B-11CJ-JARR

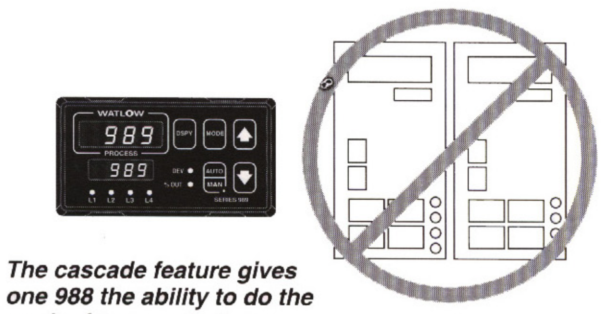


Zero-cross fired burst fire reduced radio frequency interference and extended the heater life.



Outputs:

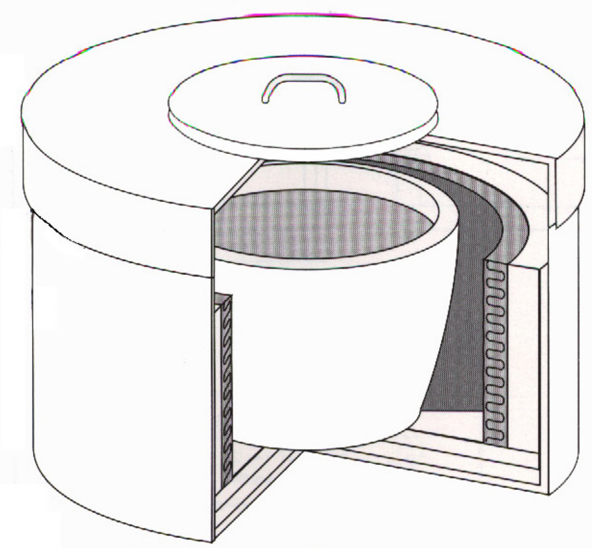
Tight control of the heater face required burst-fire control. This dictates the use of a solid-state power device. An open-collector output was chosen as the control output to interface with a Watlow QPAC SCR power control equipped with a DC-input firing card.

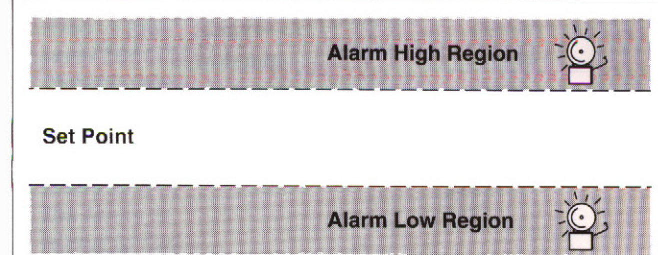


The cascade feature gives one 988 the ability to do the work of two controllers.

Software:

Cascade control using a single Series 988 controller requires the enhanced software option. Once it was configured for cascade control, Andy tuned both the inner loop (heater face temperature) and the outer loop (aluminum temperature), to increase heater life and maintain tight process control.

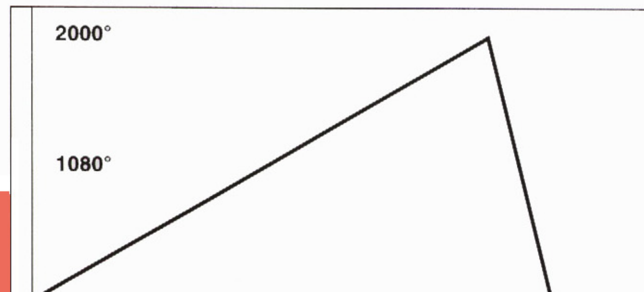




Andy configured the controller to trigger both a low-temperature and a high-temperature alarm.

Standard Features:

He configured two alarm outputs: one to indicate over-temperature on the heater face and one to warn of low aluminum temperature. It is critical to maintain aluminum above its melting point once it has melted. Also, the operator used the alarm silencing feature to prevent the alarm from being triggered at start-up.

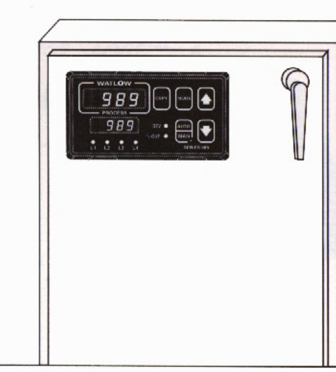


If a system component fails the limit shuts the system down.

Review and Optimize:

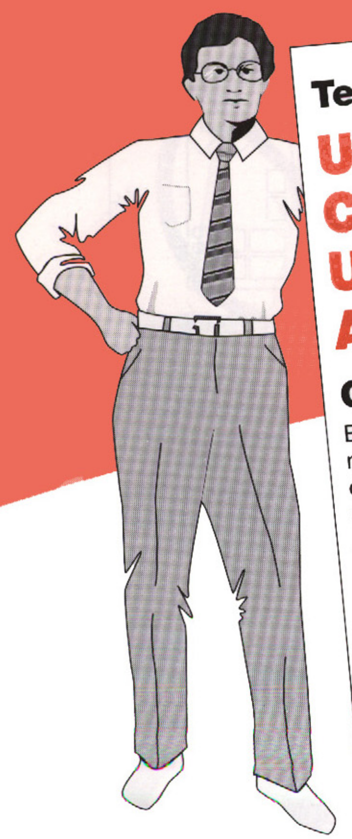
Accident prevention is a paramount concern in such a critical system. So the system was designed with a Watlow Series 92 DIN-rail mounted limit control and an external contactor to function as a limit if the aluminum reaches a dangerous temperature.

Andy choose the horizontal version of the controller because it fit the control panel well.



Hardware:

The horizontal version (989) of the controller fit nicely into the control panel. The operator also chose the high voltage (85 - 264VAC) option for power and picked a red upper and red lower display.



Test Drive:

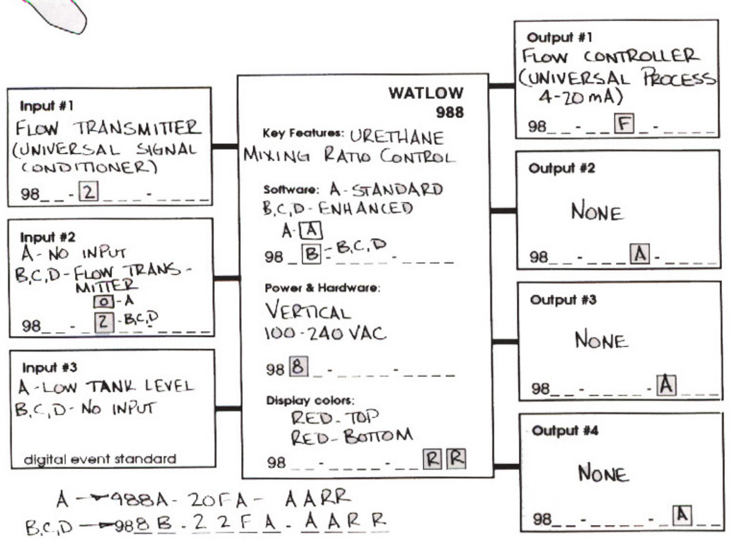
Using Ratio Control in a Urethane Mixing Application

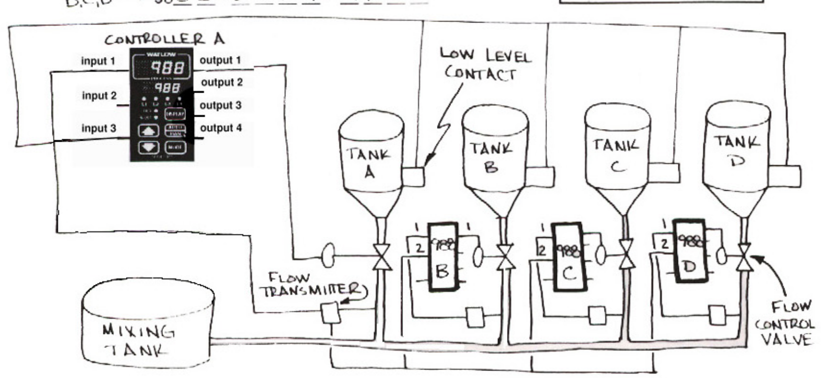
Overview:

Bob, a Watlow distributor salesman, met with his customer to determine a control scheme for mixing various resins at a specific ratio.

The system required:

- mixing up to four types of resin at specific ratios;
- control of proportioning valves for accurate mixing;
- automatic shut down if a tank is about to run out of resin.



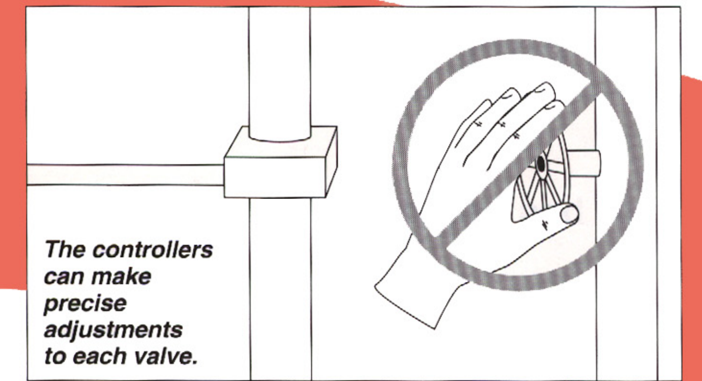


A:B:C:D
1:5:2:1

If the flow from tank A changes, the controllers will adjust the flow from the other three tanks to maintain the correct ratio.

1. Inputs:

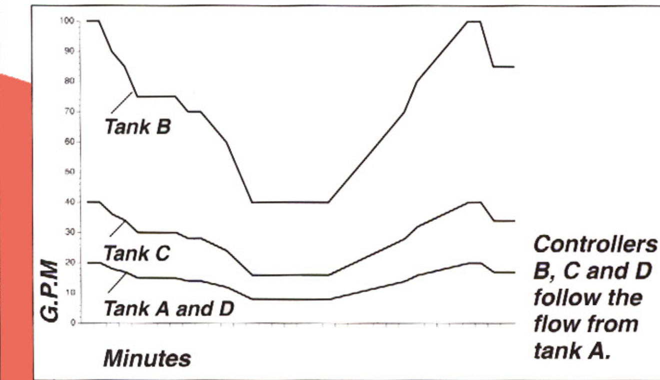
The controllers used for resin mixing require a 4-20mA process input from a flow transmitter. A second input on three controllers uses the signal from the main flow transmitter to maintain the correct mix ratios.



The controllers can make precise adjustments to each valve.

2. Outputs:

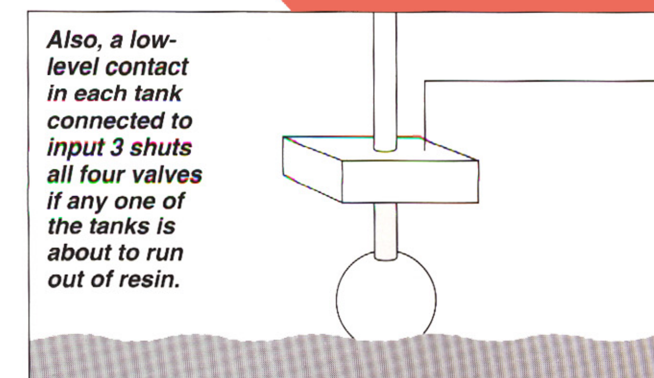
The resin flow controllers use a 4-20mA output to a proportional control valve for precise flow control.



Controllers B, C and D follow the flow from tank A.

3. Software:

Using a 988 controller for ratio control requires enhanced software. The master controller does not do ratio control, so it needs only the standard software. Each of the other three controllers uses the flow measured by the main flow transmitter to maintain the correct mix ratios, so they need enhanced software.



Also, a low-level contact in each tank connected to input 3 shuts all four valves if any one of the tanks is about to run out of resin.

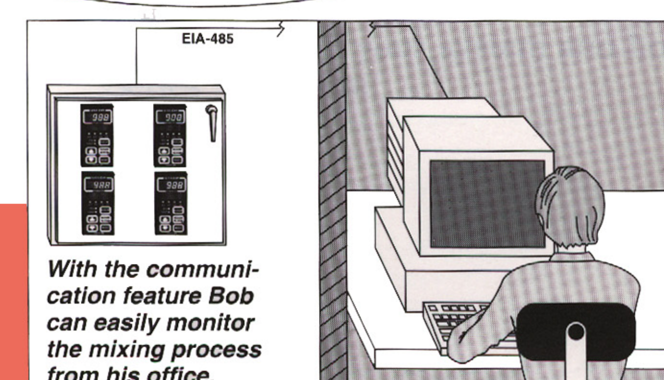
4. Standard Features:

The impedance of the 4-20mA inputs in the 988 is only 5 ohms. This allows the main flow transmitter to send a signal to all four controllers. Many controllers have 250 ohms of input impedance, which doesn't permit as many to be driven by one device.

UL recognized.

5. Hardware:

The panel containing the four controllers was built by a third-party vendor. The requirements for a UL recognized panel were easily met, thanks to the UL recognition of the Series 988 controller under UL 873 and, more importantly, UL 508.



With the communication feature Bob can easily monitor the mixing process from his office.

6. Review and Optimize:

In the final review of the application design prior to purchasing the 988s, Bob decided that in the future he wants to monitor the four controllers with a personal computer, so he added the RS-422/EIA-485 communications option to the controller part number.

Chapter Two

Basic Control Strategies and Terms

Control Strategies	2.2
Questions and Answers	2.5
Glossary	2.8

How to use this chapter:

This chapter explains control terms and strategies, especially as they apply to the Watlow Series 988 family of controllers. It will help you identify issues specific to your application, and allow you to implement the Series 988 controller in the most cost effective manner, giving you optimal control of your specific system.

Many of the decisions for system components are limited by factors not associated with the Series 988. The strategy presented here is designed to get you thinking of all the different parameters associated with your system and how the Series 988 fits in.

Basic Control Strategies and Terms

Control Strategies

Process Control

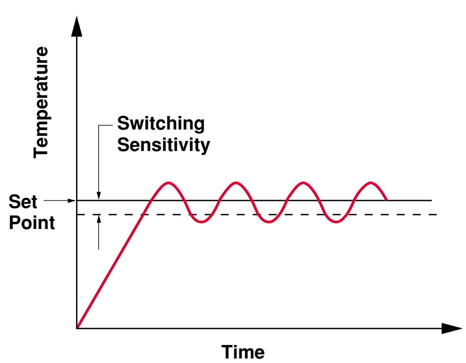
Process controls are of two basic types: open loop and closed-loop. An open-loop control device has no self-correcting feedback information. The closed loop system uses feedback information from a sensor to adjust the system. As the process changes, the feedback loop provides up-to-date status information that the controlling device uses to make self-correcting adjustments. The closed-loop control device provides much better process control.

Control Modes

A variety of control modes offer various degrees of controllability. The most common modes are on-off and PID control. The PID control category includes varying degrees of complexity that provide accurate, stable control under a variety of conditions.

ON/OFF Control

The operation of the ON/OFF control, as the name implies, turns the output device full ON or full OFF. Temperature or process sensitivity (hysterisis) is designed into the control action between the ON and OFF switching points to prevent switching the output device ON and OFF within a span that is too narrow. Switching repeatedly within such a narrow span will create a condition of intermittent, rapid switching, known as output "chattering." The process is always controlled "about set point," dictated by the switching hysterisis of the ON/OFF control. This form of control action further dictates that there will always be a certain amount of overshoot and undershoot. The degree of overshoot and undershoot will be dependent on the characteristics of the entire system.

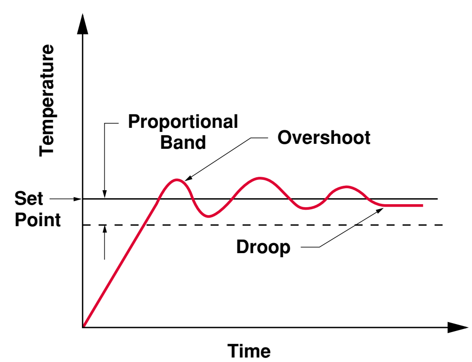


Profile produced by ON-OFF control

Time Proportioning

Time-proportioning control provides more precise control of a process. A time-proportioning control operates in the same way as an ON/OFF control, when the process is far enough away from set point to be outside the proportional band. When the process approaches set point and enters the proportional band, the output device is switched ON and OFF at the established cycle time. At the lower limit of the band, the ON time is considerably greater than the off time. As the process more closely approaches set point, the ratio of ON to OFF time changes: the amount of ON time decreases as the OFF time increases. This change in effective power to the load provides a throttling-back effect, resulting in less overshoot.

The ON and OFF cyclic action continues until a stable relationship is achieved. At that time, the system will be stabilized such that the process is controlled at a point below set point. The process stabilizes with a resultant droop. This condition will remain providing there are no work-load changes in the system.

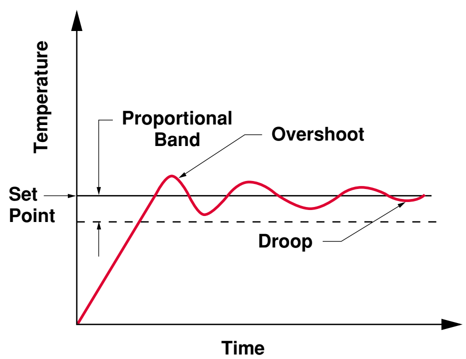


Profile developed by proportioning control

Integral

If the droop cannot be tolerated, there are ways to compensate for it. Integral (automatic reset) is an automatic adjustment to compensate for

a droop condition before it exists. An integration function takes place that automatically compensates for the difference between set point and the actual process. This integration automatically drives the process toward set point. Integration action is prevented until the process enters the proportional band. If it was



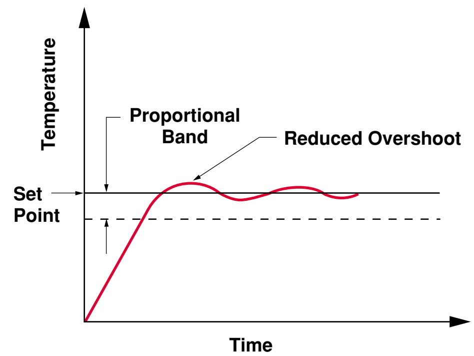
Profile developed by a proportional plus integral control

allowed to take place at any point, it would cause a condition of extreme overshoot. This function of eliminating the integration outside of the proportional band is referred to as "anti-reset windup."

Derivative

As all of the graphs have illustrated, overshoot occurs with any of the previous control methods. Overshoot may be hazardous to certain processes. It is preventable with a control function known as "derivative" (rate).

Derivative is an anticipatory function in a process control that measures the rate of change of the process and forces the control into a proportioning action on an accelerated basis to slow that change. This action prevents a large degree of overshoot on start-up and also functions to prevent overshoot when system disturbances would tend to drive the process up or down. A proportioning control with integral and derivative (PID) control provides the type of control required for difficult processes with frequent system disturbances or applications that need precision control.



Profile developed by a proportional plus integral plus derivative (PID) control

Control System Tuning

In this phase of making the system work, we will focus on the process controller as the primary component of a closed-loop system that must be adjusted for optimum performance. These adjustments provide a means to compensate for system problems. For instance, when the sensor cannot be placed in the most desirable location because of physical limitations, a PID controller can compensate for the sensor's resulting thermal lag problem.

Tuning Methods

Process controls are tuned manually or automatically. Manual tuning requires manually setting each of the controller's operating parameters. Automatic tuning, or auto-tuning, is accomplished by the 988's digital, microprocessor-based, electronic circuitry. The controller uses a program inside its memory that will calculate the correct setting for each of the controller parameters. For more information on auto-tuning with the Series 988 refer to page 3.2.

Manual Tuning

The following steps are generally applicable to most manually set process controllers. Please take note of a few precautions:

• Take your time in tuning the control system. If you do it right, it will work a long time without further attention.

• Do not change more than one control adjustment at a time, allowing the system to settle

down to a state of equilibrium before making another change.
• Remember that the time you need to spend tuning the electronic controller system is relative to the precision of control you need.

Proportional Band

The proportional band adjustment is the means of selecting the response speed (gain) or sensitivity of a proportioned controller to achieve stability in the system. The proportional band — whether measured in degrees, percent of range or other units — must be wider than the natural oscillations of the system and yet not wide enough to dampen the system response. The time proportioning output must be set to switch faster than the natural oscillation of the system, sometimes called, “system cycle time.” The tuning procedure is very simple, if you can use a recorder to monitor the actual process variable. If a recorder is not available, observe the process response and record readings over a defined time period.

If the system oscillates when the proportional band is at its narrowest setting (not zero), the adjustment of the proportional band should be increased in small increments until the oscillation stops. Because the proportional band has been tuned (adjusted) to have the controller seek stability of the system, very often an offset (droop) from the set point occurs. At this point in tuning the system, the process variable should be in a state of equilibrium, but not right on the desired set point.

Integral (Reset)

The reset adjustment is tuned at this point to correct for the droop caused by the proportional output. While it does automatically correct for offset errors, automatic reset has to be tuned to each system. Each system has its own characteristic response time (system cycle time), thus, the auto reset time constant (repeats per minute) must be tuned to match the overall system response time.

Initially auto reset should be set at the lowest number of repeats per minute (least corrective action). Increase the repeats per minute in small increments, allowing the system to settle down (stabilize) before making additional changes, until the system just starts to oscillate. Then back the setting off enough to re-establish system equilibrium.

Derivative (Rate)

Rate is the last control parameter adjustment to be made. Rate’s function is to reduce or eliminate overshoot (excursions above or below set point). It has a time base (measured in minutes) that must be tuned to work with the overall system response time (system cycle time). The initial setting for rate should be at the smallest integer of minutes possible (least corrective action). Increase the integer in small increment, then after each adjustment increase the set point moderately. Observe the approach of the actual process to set point. If it overshoots, continue to increase the rate integer in small increments. Then increase the set point moderately until optimum approach to set point is achieved. If at some point the system becomes very sluggish or cannot reach the new set point at all, too much rate (corrective action) has been adjusted into the control system. To reduce this “damping” effect, decrease the number of minutes of rate.

Recommended Tuning Reference

There are many reference books on the art of tuning electronic controllers to the systems they control. If you are not an instrument technician qualified to tune thermal systems, we suggest that you become familiar with the following reference before attempting to tune your system:

Tuning of Industrial Control Systems
by Armando B. Corripio
Published by the Instrument Society of America (ISA)
Member $48.00, list $60.00 (approx.).
Phone: (919) 549-8411

Questions and Answers

System Diagram

No matter what your application, you must start with an accurate system diagram. A blueprint of the system wiring is typically not a faxable document. When consulting the factory, it's helpful to be able to fax a system diagram similar to the hand drawings shown in the Test Drives in Chapter One. This diagram should include all inputs, outputs, the controller, the load, any alarms and any connections to other systems or equipment. This diagram should show the expected signal types and ranges at each interface point to allow you to properly order and set up your 988 controller. For the advanced user of the Series 988 this will be second nature. For the less experienced operator, putting together a diagram including all system components will allow a Watlow sales rep or factory applications engineer to review the system for correctness.

Inputs

The 988 controller accepts a wide variety of input signals and ranges, covering most temperature and process applications. Ask yourself the following questions about your inputs:

What accuracy is required for each input? (page 6.8)
- RTD's will provide the most accurate measurement in a temperature-related system.
- The accuracy of a process sensor for flow, level, pressure, etc. will depend strictly on the sensor manufacturers specifications.
- The Series 988 measures the input and updates the output 10 times per second with one input. With 2 inputs, each input is measured five times per second.

What is the wire length required to reach controller? (page 6.8)
- When designing a system using thermocouple or RTD sensors, if the lead length is excessive, errors may be introduced into the system. By using a signal transmitter to convert the thermocouple or RTD signal to a process signal the errors can be avoided.

Is cost a factor in the sensor selection?
- Typically, a thermocouple costs less than an RTD sensor. However, it almost never pays to spend less on a sensor, which is arguably the most important part of the thermal system.
- Process sensors can vary widely in cost. Other factors, such as accuracy, response time and durability, must be weighed.

Will this be a grounded or ungrounded application? (page 5.8)
- Although inputs are electrically isolated from outputs in the 988, you must determine if other sources of ground loops in the system may affect the sensor. This can occur, in the Series 988, if there are two grounded inputs or if an output is tied to an input, such as using a transmitter power supply output to power a thermocouple transmitter.

Is the process relatively fixed or widely varying — what is the range? (page 6.8)
- Make sure you check (and re-check) the ranges of the input options available in the 988. Although the 988 can operate outside the ANSI ranges for specific thermocouples and RTD's, it is not recommended and will shorten the life of the sensor.

Are there concerns over electrical noise immunity?
- Although the Series 988 is thoroughly tested for electrical noise immunity, it is paramount that you follow good engineering practices when designing the placement of the sensor and power wires. Refer to the *Series 988 Users Manual* and the *Watlow Catalog*.

Outputs

The outputs command the system to heat, cool, turn ON and OFF, and also trigger other actions in this system or related systems.

It is very important that you maintain total control over the process. External limits or other devices to disable the outputs can protect system components and provide an added layer of safety. Consider the following:

How frequently will the output need to cycle to control the process? (page 6.8)

- What is frequent? In order to tightly control a process, the more frequent the better. Unless absolutely necessary, mechanical relays should not be used as the control output. A typical mechanical relay application cycles ON and OFF 86,400 times over a period of one month (30 second cycle time, 24 hours per day). The mechanical relay option is only warranted for 100,000 cycles.

- With a solid-state output a variable-time-base burst fire option can provide the tightest load control. Make sure the power control is compatible with the burst-fire output. (page 3.3)

What actuator interfaces are required? (page 6.8)
- Typically the output of the Series 988 does not directly control the load. Instead it acts as a pilot-duty output interfacing with another device that actually controls the load. If this is the case in your application, make sure that the output of the Series 988 is compatible with the input of the external device.

What alarm or annunciation outputs are required? (page 5.1)
- The alarm options in the Series 988 can be used to alert an operator to a system malfunction. These outputs should not be used as safety limits to protect system components or personnel. A separate safety limit device should be used in any system where damage or injury could occur due to a system component failure.

How should the alarms operate? (page 5.1)
- The alarm options can be field-configured to function in any fashion. A process alarm can be used to warn the operator of impending equipment damage. A deviation alarm can be used to warn that the system is operating outside of the desired specifications. Each alarm can be set for latching or non-latching, silencing and reverse or normal logic.

Should you monitor the load current? (page 3.7)
- While this option is available as an input, it is important to note that this feature in the Series 988 is not currently available when using a process output (4-20mA, 0-5VDC, etc.). Also, it limits the minimum on-time of the output.

Does the process require a retransmit output? (page 3.12)
- Output 3 can be used as either a 4-20 or 0-20mA output or as a 0-5, 1-5 or 0-10VDC output to retransmit the process value of either of the inputs or the set point value. It allows the controller to function as a master controller in a master-remote application or to retransmit a process value to a chart recorder.

What types of monitoring of the outputs is required? (page 3.4)
- The retransmit option is one way to monitor the system status.
- A serial communications option can be used to monitor and/or change all the parameters in the controller. With the EIA-485 option up to 32 controllers can be monitored from a single communications port on a personal computer, over distances of 4000 feet. The RS-422 option can address up to 10 controllers over 4000 feet, and the RS-232 option can address a single control over a distance of 50 feet. Make sure the computer or other monitoring device is equipped with the correct serial communications card and that the baud rate and other capabilities are compatable.

Controller Environment

There are several factors to consider concerning the environment that the Series 988 controller operates in:

What are the physical dimensions of the enclosure? (page 6.4)
- The Series 988 family of controls has a behind-panel depth of 4.06 inches, allowing the control to fit an enclosure with a depth of 6.0 inches. When mounting more than one controller in a panel we recommend a minimum spacing of 1.66 inches between controllers.

What is the ambient temperature inside the enclosure? (page 6.8)
- The Series 988 can operate in ambient temperatures as low as 32°F (0°C) and as high as 150°F (65°C). The enclosure requires a non-

condensing atmosphere, because the vented case is susceptible to dripping water. If necessary, include an enclosure heater in your system to maintain the proper environment.

Is the front panel subject to spray or hose-down conditions? (page 6.8)
- The Series 988 has a NEMA 4X-rated front panel. This rating allows the controller to be hosed down directly without damaging the controller. Two gaskets protect the controller: one seals the bezel of the control while the other seals the controller face plate and the panel cutout. When installing the controller be sure that these gaskets are not twisted.

What are the agency requirements for the controller and the system? (page 6.8)
- The Series 988 has a UL 873 and UL 508 recognition. CSA recognition is pending. Also, the NEMA 4X rating was certified independently by UL under UL 50X.

Controller Operation

Operation of the Series 988 can be broken down into three concerns: setup; operation; and maintenance. The questions you ask yourself should examine each of these areas.

Does the system have any interactive process variables? (Chapter 4)
- Interactive process variables include ratio, differential or cascade control or slidewire feedback of valve position. Also, heater current measurements can be used to detect system faults.

Is an event input useful in this application? (page 3.6)
- Before finalizing the design check out this basic option. The event input can expand the user-friendliness and/or security of your system.

Is ramp to set point required? On start up? On set point change? (page 3.10)
- Many systems are susceptible to damage if the process changes too rapidly. The ramp to set point feature can minimize system stress.

How should the controller respond to an error? (page 5.6)
- In the event of an error, system response is critical. Some systems might require that the control output turn full ON to provide cooling. Other systems would require that the control outputs be turned OFF. The design of some systems might allow the control to continue operating in the manual mode without operator action. All of these options are available with the Series 988.

Are you shipping products overseas? (page 2.3)
- In some countries and in certain markets in the U.S. the default units may be either degrees C or degrees F and the PID parameters might use proportional (in percent of span), integral and derivative or proportional (in degrees), reset and rate. The 988 can switch between these default sets to suit the user's preference.

What level of operator security do you need? (page 5.7)
- The Series 988 provides numerous levels of both software and hardware lockout. Refer to page 4.5 for more information on lockout.

What do you do if a system component fails? (page 5.5)
- When investigating a system failure, the Series 988's Diagnostics menu can be used to monitor inputs and selectively activate outputs. The menu also shows the software revision and the I/O types.

What about field calibration?
- All Watlow microprocessor-based controls can be field calibrated with the right equipment. The calibration manual for the Series 988 family of controllers is available upon request.

Putting It All Together

You should now have a good idea of what types of questions to ask when designing your system with the Series 988. We suggest that you read through the rest of this chapter and Chapters Three through Seven for more detailed information on the features available in the Series 988. If you are already familiar with the 988, skip to Chapter Seven to select the 988 that fits your application.

Glossary

annunciator — a device that uses pilot lamps to indicate the former or existing condition of a system being monitored.

ANSI — American National Standards Institute.

burst fire — output that switches full AC cycles ON and OFF repeatedly. Zero-cross burst fire switches only at the zero-voltage point of the AC sine wave. Variable-time-base burst fire would switch ON and OFF 30 times a second to achieve a 50-percent power level with a 60-cycle AC power supply. Also see "zero switching."

calibration offset — adjustment to the actual process input and to the process values the Series 988 uses for display and control.

cascade — control algorithm in which the output of an outer control loop is the set point for an inner loop. The inner loop, in turn, determines the control action.

closed loop — control system that uses a sensing device for process variable feedback.

cold junction — point of connection between thermocouple metals and the electronic instrument.

cold junction compensation — electronic means to compensate for the effective temperature at the cold junction.

current transformer — a transformer, designed for measuring electrical current, with its primary winding connected in series with a circuit carrying the current to be measured.

dead band — The dead band setting determines the amount of interaction between heat (reverse acting) and cool (direct acting) control outputs.

default parameters — the parameters, or programmed instructions, permanently stored in the microprocessor software.

derivative — anticipatory action that senses the rate of change of the process, and compensates to minimize overshoot and undershoot. Also see "rate."

differential control — With enhanced software, the Series 988 controller can control one process in relation to the difference of a second process. A set point is added to the measured value of the second process. This sum is used as the set point for the input 1 process value.

DIN — Deutsche Industrial Norms, a widely recognized German standard for engineering units.

droop — difference between the set point and stabilized process value.

duplex control — With enhanced software, duplex control splits a single process output into two individual outputs. For example, a 4-20mA output is split into a 4-12mA direct acting (cooling) output and a 12-20mA reverse acting (heating) output, thus allowing one control output to function as two.

duty cycle — percentage of load-ON time relative to total-cycle time.

external transmitter power supply — a DC voltage source of power for external devices.

filter — as applied to the Series 988, a low-pass filter designed to minimize display or process input fluctuations.

form A — single-pole, single-throw relay that only utilizes the normally open (N.O.) and common contacts. These contacts close when the relay coil is energized. The contacts open when power is removed from the coil.

form B — single-pole, single-throw relay that only utilizes the normally closed (N.C.) and common contacts. These contacts will open when the relay coil is energized. The contacts will close when power is removed from the coil.

form C — single-pole, double-throw relay that utilizes the normally open (N.O.), normally closed (N.C.) and common contacts. The user has the option of wiring for a form A or form B contact. Refer to the form A and form B above for more information.

hunting — oscillation or fluctuation of the process between the set point and process variable.

hysteresis — in ON/OFF control, the process change necessary to change the output from full on to full off.

input linearization — For thermocouple and RTD inputs, the process variable is automatically linearized. Certain flow transmitters generate a non-linear signal corresponding to the flow being measured. The square root of the signal is calculated to generate a linear signal.

integral — control action that automatically eliminates the offset, or “droop,” between the set point and actual process value. Also see “reset.”

isolation — Electrical separation of sensor from high voltage circuitry. Allows use of grounded or ungrounded sensing element.

JIS — Joint Industrial Standards. Also Japanese Industrial Standards Committee (JISC). Establishes standards for equipment and components.

linearization — the extraction of a linear signal from the non-linear signal of a flow transmitter. Also see “input linearization.”

NEMA 4X — a front-panel rating that certifies the control as washdown capable and corrosion resistant.

ON/OFF control — control of a process by turning the output full ON below set point and full off above set point.

open loop — control system without sensory feedback.

output — action in response to difference between the set point and process variable.

overshoot — condition in which the process exceeds set point due to initial power up or process changes.

P control — proportioning control.

PD control — proportioning control with derivative (rate) action.

PDR control — proportional derivative control with manual reset is used in fast responding systems where the reset causes instabilities. With PDR control, an operator can enter a manual reset value that will eliminate any droop in the system. The option requires enhanced software.

PI control — proportioning control with integral (auto-reset) action.

PID control — proportioning control with integral (auto-reset) and derivative (rate) action.

process variable — regulated system parameter, such as time, temperature, flow, humidity, etc.

proportional band — span of the process from the set point within which time proportional control action takes place.

proportioning control — See "time proportioning control."

rate band — a thermal control band that defines where the rate (derivative) function begins. The Series 988 rate band centers on the set point and is twice the width of the proportional band.

ratio — application in which the flow of an uncontrolled stream is measured and used to maintain the flow of a controlled stream at a ratio to the uncontrolled stream.

reference junction — synonymous with cold junction. Also see “cold junction.”

retransmit — an analog signal representing a control variable, either the process values or the set point values.

RTD — resistance temperature detector. Resistive temperature-sensing device that displays a positive temperature coefficient.

slidewire feedback — closed-loop, valve-actuator control using a potentiometer to indicate valve position.

switching sensitivity — in ON/OFF control, the process value change necessary to change the output from full on to full off.

thermal system — a regulated environment consisting of a heat source, heat transfer medium, sensing device and a process variable control instrument.

thermocouple — temperature-sensing device constructed of two dissimilar metals that generates a measurable, predictable voltage that corresponds to its temperature.

thermocouple break protection — fail-safe operation that assures output shutdown upon an open thermocouple condition.

three-mode control — proportioning control with integral (reset) and derivative (rate). Also see “PID.”

time proportioning control — action that varies the amount of on and off time when “close” to the set point, i.e., in the proportional band. This variance is proportional to the difference between the set point and the actual process. In other words, the amount of time the output relay is energized depends on the system process value.

transmitter power supply — When Option “T” is ordered for output 2, 3 or 4, the Series 988 can supply power to external signal conditioners, transducers or transmitters. With internal DIP switches, the user selects between 5, 12 or 20VDC at 30mA ratings.

zero-cross — Action that provides output switching only at the zero-voltage crossing points of the AC sine wave. Also see “burst fire.”

Chapter Three

General Software Features

Auto-tune	3.2
Burst fire	3.3
Communications	3.4
Dead band	3.5
Digital event	3.6
Heater current	3.7
Input filter	3.8
Input linearization	3.9
Ramp to set point	3.10
Remote set point	3.11
Retransmit (master/remote)	3.12
Slidewire feedback	3.13

How to use this chapter:

This chapter describes the software features that are available in Watlow Series 988 controllers. Enhanced software options provide additional features that are described in Chapter Four.

Auto-tune

Overview:

The auto-tune feature allows the controller to manipulate the process and calculate PID values based on the process response. This relieves the operator from the tedious task of manually tuning the PID parameters to match the characteristics of the thermal system.

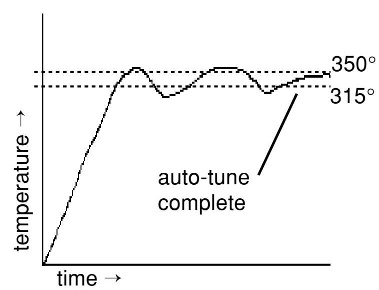
The point at which the auto-tune takes place is determined by the auto-tune set point AtSP parameter. It is adjustable from 50 percent to 150 percent of the current set point, with 90 percent being the factory default setting. If the auto-tune set point is 90 and the current setpoint is 300 degrees, the control goes into ON/OFF mode of control at 270 degrees (300 deg. x 0.9). The displayed setpoint is unchanged and the bottom display information alternates with tune tunE at a one-second rate until the auto-tune is completed. Any changes to the set point during an auto-tune will cause the auto-tune sequence to start over, based on the new set point.

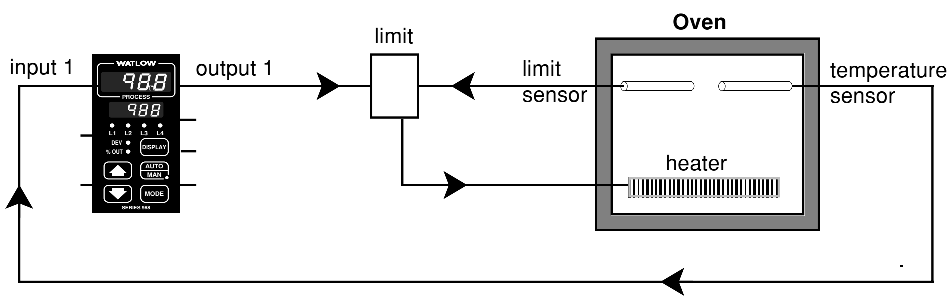
During an auto-tune the controller monitors how fast the process increases and decreases, and from this information calculates proportional band, reset and rate values and automatically enters them into non-volatile memory.

To abort an auto-tune, set the auto-tune prompt AUt to OFF or press the AUTO/MAN key twice, or cycle the power OFF and ON. The previous PID parameters will be restored.

Requirements

The Series 988 can be ordered with two complete sets of heat/cool PID sets. This requires the enhanced software option. A single set of PID parameters is available with the standard software option.





Sample Application:

In this example the oven needs to hold at 350 degrees F. To complete the tuning sequence set the set point for 350 degrees and auto-tune by setting the auto-tune prompt to PidA.

Burst Fire

Overview

Variable, time-base burst firing from the 988 provides a command signal to an SSR or SCR firing card that translates into a burst of AC cycles. The output is zero-cross fired and always allows at least one AC cycle to pass within the variable time base. The fact that we are zero-cross switching the power device means we enjoy the benefits of low radio frequency (RFI) noise. Burst firing is the preferred mode to control resistive loads.

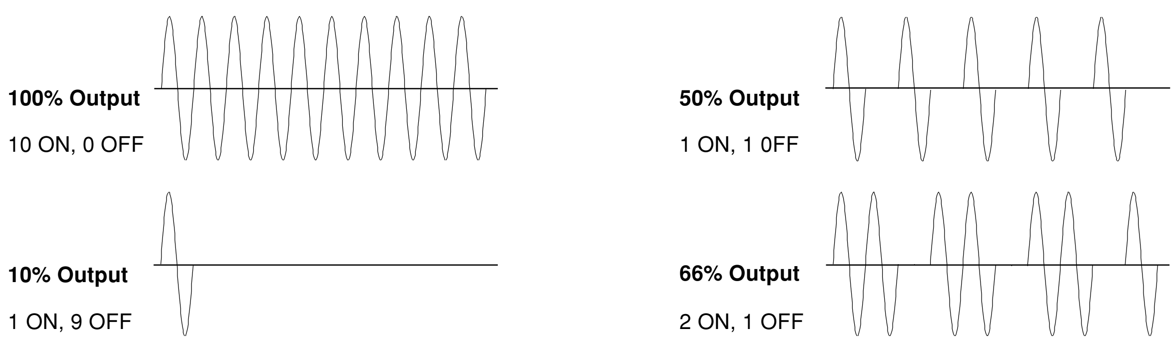
The burst fire time base in the 988 varies from a maximum 1.66-second time base (1-percent output) down to a 33.3-millisecond time base (50-percent output). The examples below show how the time base varies depending on the percent output.

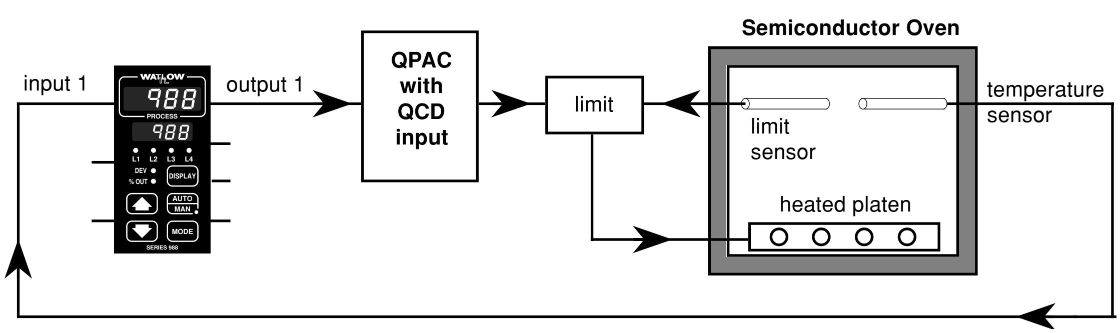
Requirements

The 988 family has built in zero-cross detection circuitry. Therefore special firing circuitry is normally not required for triggering SCR’s. To enable burst fire the 988 must have an open collector or solid-state relay output. The feature is enabled by selecting burst fire brSt at the cycle time prompt for the appropriate output.

<u>You should note that the short time bases used by burst fire makes it incompatible with the heater current feature (see page 3.7).</u> The heater current option requires a minimum of 300 msec. ON-time to get a reading.

Only the 988 and 989 can use the burst fire feature. <u>The low-voltage units (986 and 987) cannot use burst firing.</u>





Sample Application

The 988 is being used to control a heated platen in a semiconductor oven. Previously it required a power control requiring a 4-20mA signal to implement burst-fire control. We have replaced the power control with a Watlow Loyola QPAC with a QCD card that accepts a signal directly from an open-collector output of the 988. This gives smooth control at a lower overall system cost.

General Software Features

Communications

Overview

The serial communications feature allows the Series 988 family to receive commands from and transmit data to a master device, usually a computer. Any function that can be performed via the front panel, can also be accomplished using the serial communications port, allowing you to operate the controller from a computer and to store process data on a computer.

The 988 is available with a choice of serial hardware interfaces. An RS-232 interface allows for one master (computer) and one controller, with a maximum network length of 50 feet (15 meters).

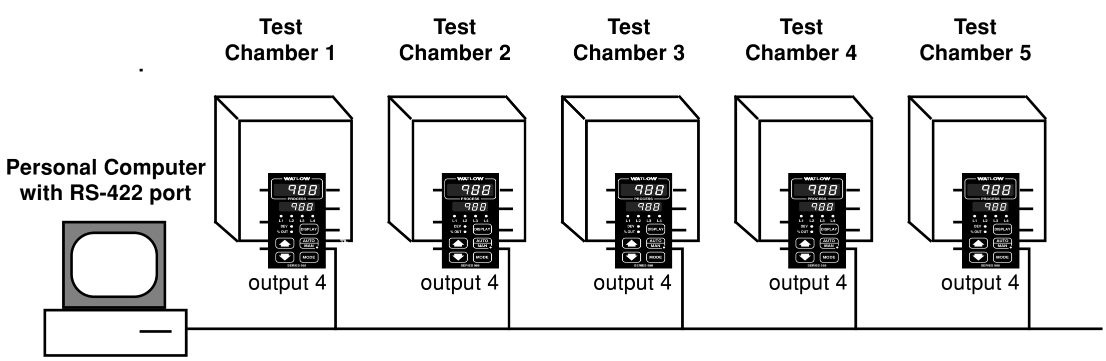
The EIA-485/RS-422 option equips the controller for a multi-drop interface: up to 32 total network devices with EIA-485 and up to 10 total network devices with RS-422. Each controller will have its own unique address. The total maximum network length is 4,000 feet (1,219 meters). These are isolated interfaces.

To select between EIA-485 or RS-422, enter the setup prompts by holding the increment (up-arrow) and decrement (down-arrow) keys simultaneously until setup SEt appears in the bottom display. Use the decrement key to select the Communications menu COM. The interface prompt IntF selects between 485 or 422.

Other parameters that must be configured in the Communications menu COM are the baud rate bAUd, data bits and parity dAtA, protocol Prot, and device address Addr. The protocol Prot prompt must be set to full FULL (ANSI X3.28 2.2-A3) if multiple devices are used with the EIA-485 or RS-422 interface. If the full protocol is selected, a device address must be selected at the address prompt Addr. For RS-232, full FULL or on On (XON/XOFF) protocol may be selected.

Requirements

Choose which interface your application will use: RS-232 serial communications; EIA-485; or RS-422 serial communications. The computer must have a compatible serial port.



Sample Application

A test engineer uses 988's to control the temperatures of several automated test chambers. His computer is linked to the controllers through its RS-422 serial communications port. His computer program monitors the temperatures of the 988's and initiates automatic test sequences when certain program parameters have been met. After completing a sequence, the computer loads the next temperature to the controller. The computer periodically interrogates each controller for its process temperature, set point and alarm status. This information is stored on a disk to provide test verification data for the completed products.

Dead band

Overview

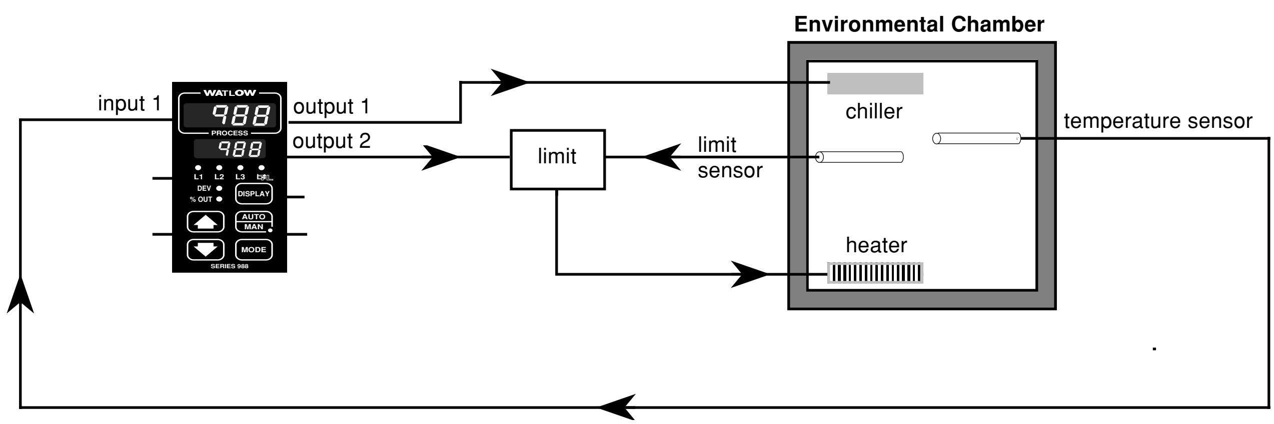
The dead band prompts, db A and db b, located in the PID menus, determine the amount of interaction between heat (reverse acting) and cool (direct acting) control outputs. The dead band directly offsets the target set point of the cool control output.

With a positive dead band, both control outputs will never be on at the same time. With the process in a positive dead band, the output value is determined by adding the percent heat output to the percent cool output and only applying the result to the correct output — cooling action if the sum is negative and heating action if it is positive.

If the dead band is set to a negative value, the heat and cool outputs can both be ON at the same time.

Requirements

The dead band feature is standard on any Series 988 controller with two control outputs. The dead band prompts will appear if the control outputs are configured for heat/cool or cool/heat.



Sample Application

An engineer for an environmental chamber manufacturer, who is designing the heating and cooling system for a new chamber, wants to minimize the energy costs of operating the chamber. She has chosen the 988 and will configure the heat and cool outputs with a positive dead band.

When the chamber temperature is near ambient the cooling and heating systems had a tendency to buck one another, resulting in inefficient use of energy. The engineer started with a dead band of five degrees, but in the process of tuning the system for optimal control, the setting was reduced to two degrees. This made the system more energy efficient and reduced wear on the refrigeration system.

Digital Event

Overview

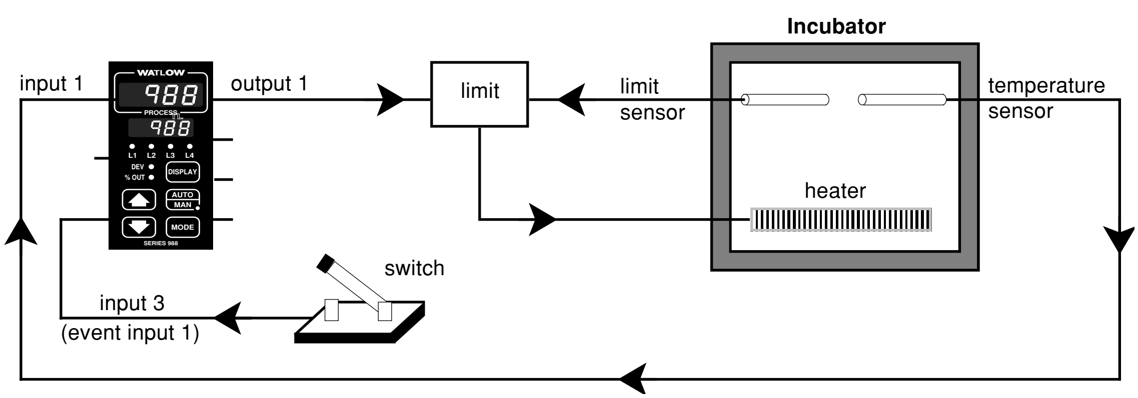
The digital event input options on the Series 988 controller allow the operator to select one of several software functions with the close of a customer-supplied switch or by a change in DC voltage.

The list below outlines the functions that can be controlled with the digital event input.

Idle set point IdSP lets the operator select, with the close of a switch, a second (idle) set point.
Turn control outputs OFF OFF allows a closed input to inhibit the control outputs.
Alarm reset ALr resets alarms from a remote location with a momentary closed input.
Switch PID sets Pid selects between PID set A or B (requires enhanced software).
Remote set point rSP switches between local and remote set points.
Front panel lockout LOC locks out the front panel keys to prevent tampering.
Control output action Actn switches the control action of Output 1 from heating to cooling, or vise versa.

Requirements

A single digital event input is standard on all controls. A second digital input is available as an option for Input 2.



Sample Application

A manufacturing engineer is building an application that needs to switch to an idle temperature at the end of a batch and maintain that temperature until the next batch is loaded, with minimum operator interaction.

By connecting an external switch to the digital event input, he can select either the operating temperature or the idle temperature with the flip of a switch. The idle set point prompt is enabled by setting the event input 1 prompt Ei1, in the Global menu, to the idle set point IdSP. The idle set point value is accessed by pressing the MODE key from anywhere in the display loop. When the switch closes, the lower display will indicate the idle set point, and the controller will maintain this new set point.

Heater Current

Overview

The heater current feature measures and responds to heater current in a system. This is an ideal method for detecting heater loss in multiple heater applications. The current is measured when output 1 is ON. For instance, if a system has five, 10-amp heaters, the heater current input measures 50 amps regardless of the percent output.

To view the heater current press the DISPLAY key and advance to the process 2 prompt Pr2. The upper display indicates the last valid current reading.

The input 2 prompt In2 under the Input menu InPt can be set to current Curr or loop error detect LooP. Current Curr allows you to monitor heater current and set alarm set points based on high and low heater current values. Alarms can only be configured as process alarms (see Alarms, page 5.2). Setting to loop error detect LooP enables monitoring and alarm functions, and also triggers an error and shuts OFF all outputs if current is present with output 1 OFF or when no current is present and output 1 power is more than zero.

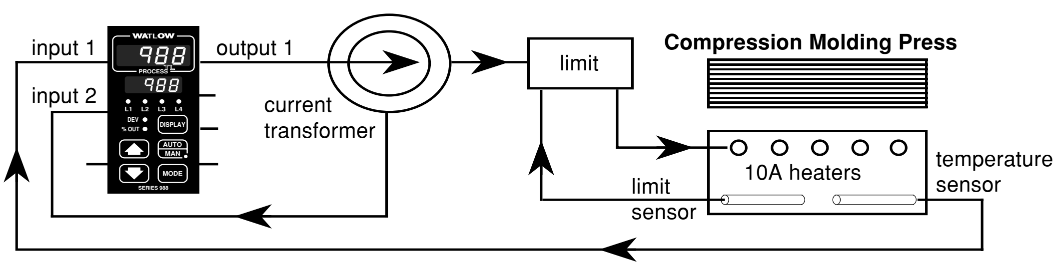
There are limits associated with this feature:

- <u>To obtain a reading, the output ON-time must be a minimum of 0.3 seconds.</u> To calculate this, multiply the percent output by the cycle time setting. Example: With 30-percent output and a 2.0 second cycle time, the on-time would be: 0.30 x 2.0 = 0.6 seconds. This would yield a valid reading. If a valid reading is not possible, the 988 will display the last valid reading.
- <u>It will not function with burst-fire outputs.</u> This does not necessarily apply to the loop error detect feature. If enabled, any current detected with no output triggers an error.
- <u>It will not function when the 988 has a process output for output 1.</u> A known cycle time is required to detect the current. There is no cycle time associated with process outputs.

The maximum signal the input can accept from the current transformer secondary is 50mA. So, you must calculate the output range of the current transformer before wiring the system.

Requirements

Choose the heater current option for input 2. <u>Output 1 cannot be used as a process output.</u> Heater current monitors only output 1.



Sample Application

The Series 988 controls the lower platen of a compression molding press that contains five, 10-ampere heaters. A 50A:50mA current transformer is used to monitor heater current. Set the input 2 prompt In2 to current Curr, the range low 2 prompt rL2 to 0 and the range high 2 prompt rH2 to 50. Find the range high 2 value with the following equation:

$$\text{range high 2} = \frac{\text{(maximum CT primary current (load current))}}{\text{(maximum output from CT secondary (input))}} \times 50\text{mA}$$

The application uses a Watlow current transformer (CT) part# 16-0233, which has a maximum input of 50 amperes, which corresponds to a maximum output of 50mA.

$$\text{range high 2} = \frac{\text{(50Amps)}}{\text{50mA}} \times 50\text{mA}$$

Solving for rH2 gives you 50. This is the range high 2 setting.

Input Filter

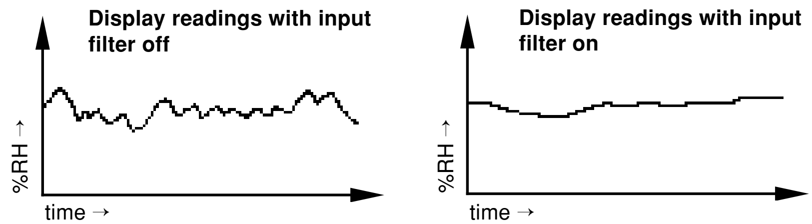
Overview

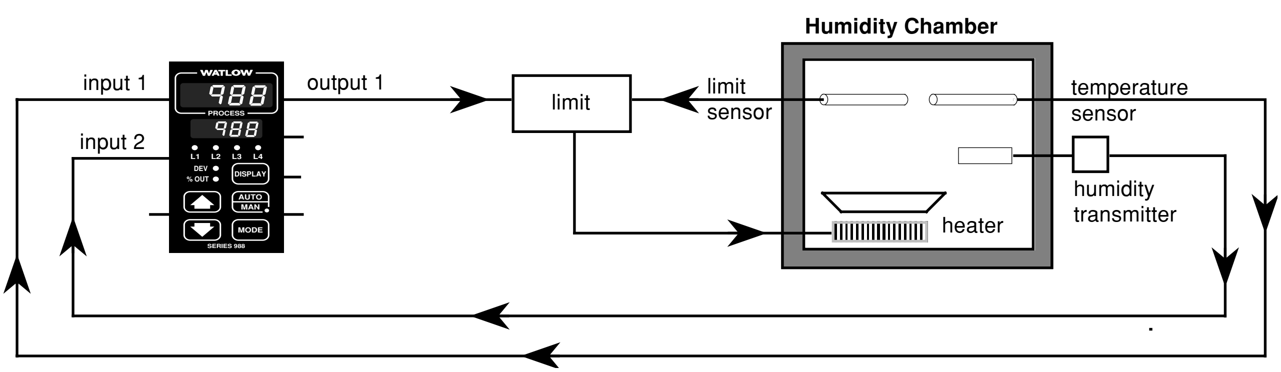
In certain applications the process being measured can be unstable, which makes it difficult to control and also makes the constantly changing display difficult to read. The Series 988 input filter can solve these problems by smoothing out just the display or the display and the input signal.

You can set a time constant, in seconds, for a low-pass filter that will affect the display only, or you can configure the option to filter the input signal itself. Use this feature with caution, because a large time constant could hide system upsets.

Requirements

This feature is standard on all Series 988 controllers.





Sample Application

A Series 988 controls the humidity in an environmental chamber. The relative humidity (RH) sensor provides a 4-20mA signal over a 0-100% RH range. The sensor is very sensitive to changes caused by air flow in the chamber. The turbulence in the chamber has the 988 display jumping two to three percent. To remove this display dithering the filter time constant Ftr1 for input 1 is set to 2 seconds. This will smooth the display and provide a more realistic reading.

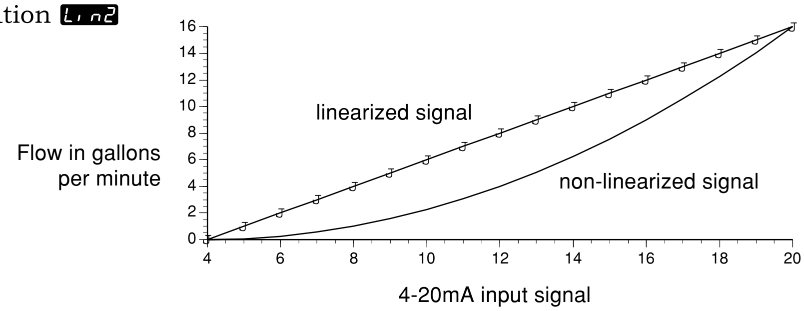
Input Linearization

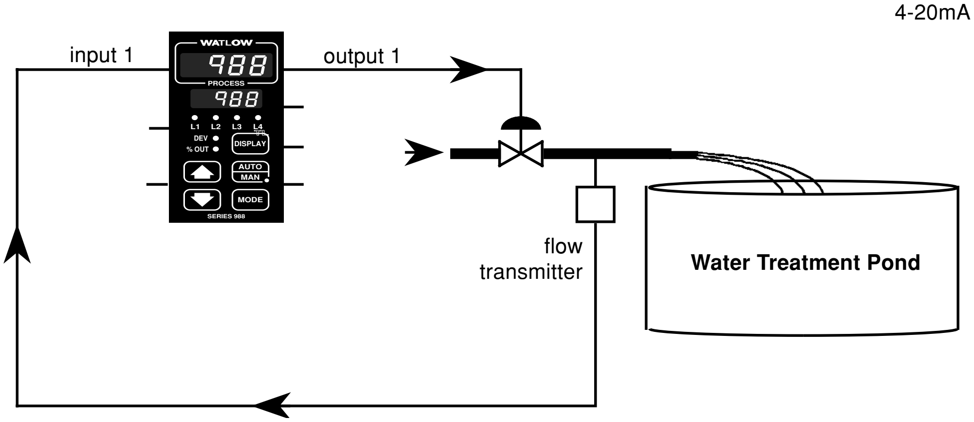
Overview:

In many flow applications the output signal from a flow transmitter represents a squared value of the actual flow. The square root must be extracted from the signal to make it useful to the operator. Many flow transmitters offer this feature in the transmitter itself, but this can add significantly to the cost. Using the square root extraction option in the Series 988 controller can save the operator money. The feature is enabled simply by setting input 1 linearization Lin1 or input 2 linearization Lin2 to square root extraction root.

Requirements:

The square root extraction feature is standard on any Series 988 controller with universal signal conditioner inputs. The linearization prompt will appear if a process input is selected via the universal signal conditioner DIP switches.





Sample Application:

A waste water process engineer needs to control the flow of a solution to be mixed with waste water for treatment of the water. The transmitter provides a 4-20mA output without square root extraction. The engineer used the Series 988 with a universal signal conditioner input and a 4-20mA process output to control the flow. The input signal was linearized using the square root extraction feature of the 988.

The above system has a flow range of 0 to 16 gallons per minute. The range low and range high parameters for input 1 would be set to 0 and 16 respectively. The input 1 linearization prompt Lin1 would then be set to square root extraction root. You can see from the above graph that without square root extraction to linearize the signal it would not be useful for controlling the process.

Ramp To Set Point

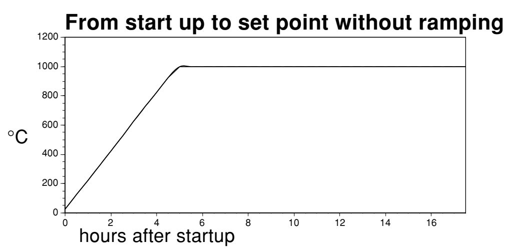
Overview

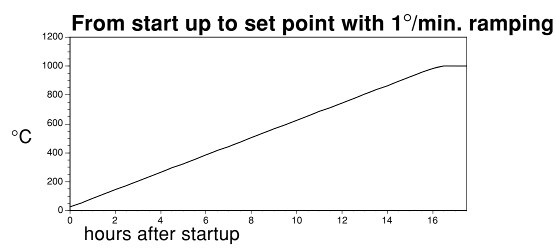
Ramp to set point enables the 988 to ramp the set point at a user defined rate. This allows the 988 to start up a system or change between set points at a rate that will not stress the product or system components. The ramp rate is defined in degrees per minute. Ramp to set point can be initiated at start up only, or at start up and also on any set point changes.

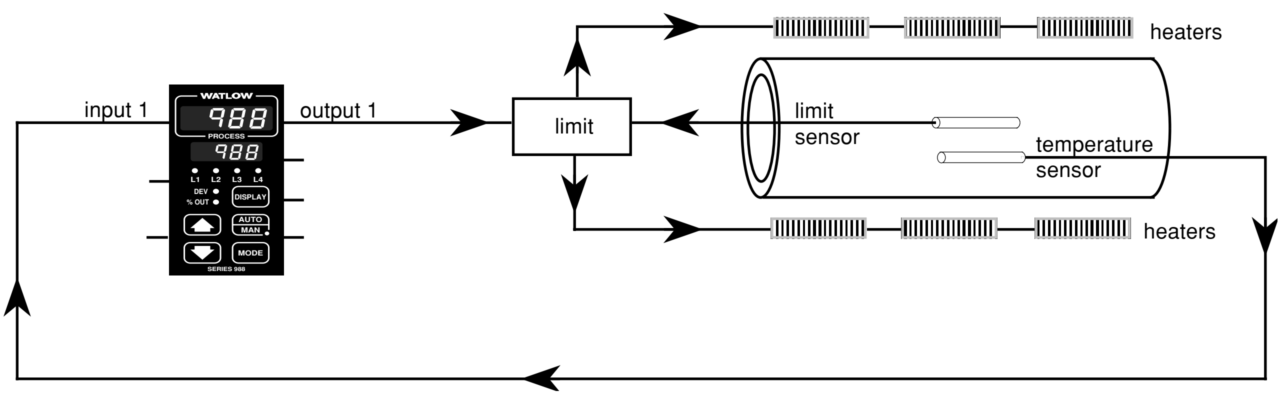
When a ramp is initiated, the starting point for the ramp is the current process value. If the ramp is initiated on start up, the 988 looks at the process value upon power up, and uses that value as the starting point for the ramp. If a set point change initiates the ramp to set point function, the 988 looks at the process value when the change is made and uses that value as the starting point for the ramp. If the set point is changed during a ramp, the process value at the time of the change becomes the starting point for the new ramp.

Requirements

This feature is standard on all units.







Sample Application

An engineer needs to control the temperature of a muffle furnace. The furnace set point must be ramped up at a defined rate to prevent stressing the muffle and other system components. By enabling the ramp to set point function in the 988, the engineer can control the rate at which the set point will rise. Ramp to set point is enabled in the Global menu using the ramping function prompt rP. To ramp on start up only, select start Strt. To ramp on start up and on any set point changes, select set point StPt. The ramp rate rAtE is in degrees per minute.

For further protection of the system, output 2, 3 or 4 can be configured as a rate alarm, monitoring the rate of increase or decrease in the process variable on input 1. The alarm low A2LO and alarm high A2HI prompts (The "2" in these examples refer to output 2.) establish the ramp-down and ramp-up rate set points, respectively, in degrees per minute.

Remote Set Point

Overview

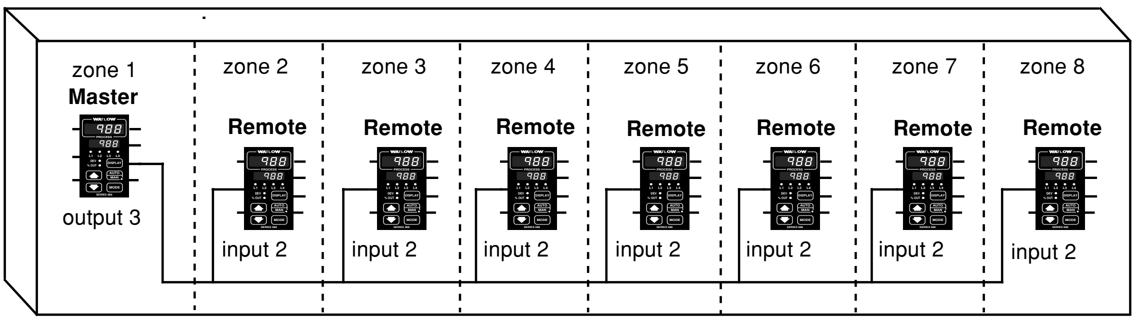
The remote set point feature allows the 988 to use a thermocouple, RTD or process signal at input 2, to establish the set point. This feature gives the 988 the ability to have its set point value manipulated by an external source. A common application would use one ramping controller with a set-point retransmit output to ramp multiple 988's using the remote set point. Or you could use an analog output from a PLC to send set point values to a 988.

Requirements

Input 2 must be either a thermocouple or universal signal conditioner, options 1 or 2.

If the application uses a master controller, choose one of the retransmit options — M (0-20, 4-20mA) or N (0-5, 1-5 or 0-10VDC) — for output 3 of the master.

Match input and output impedances.



Sample Application

An engineer has a machine with eight independent zones of heat. He wants to to change set points on all zones without having to adjust each control individually. This can be achieved using a 988 with a 0-5VDC retransmit output as the master controller. The seven remote 988's will use the 0-5VDC signal on input 2 as a remote set point. When the set point is changed on the master controller, the retransmit output changes the set points of the seven remote controllers. By enabling the ramp to set point feature in the master 988, all eight zones are ramped up to set point at a user-defined rate on power up.

The retransmit output from the master 988 is set so that 0VDC represents 0°F and 5VDC represents 800°F. On the remote controllers, set the input 2 DIP switch to the position for the 0-5, 1-5, 0-10VDC process input. In the Input menu, under the input 2 prompt In2, select 0-5. The remote set point prompt rSP should be set to ON On and decimal 2 dEC2 set to 0. The range low 2 rL2 and the range high 2 rH2 parameters will establish the scaling for the remote set point input. Range low 2 should be set to 0 and range high 2 should be set to 800. To operate a specific zone ten degrees hotter than the others, increase the range low 2 rL2 to 10 and the range high 2 rH2 to 810.

With remote set point rSP enabled and local L selected under the local-remote prompt L-r in the System menu, the set point is adjusted using the increment (up-arrow) and decrement (down-arrow) keys. Selecting remote r under the local-remote prompt L-r, disables the increment and decrement keys, allowing the set point value to be manipulated via the input 2 signal.

General Software Features

Retransmit

Overview:

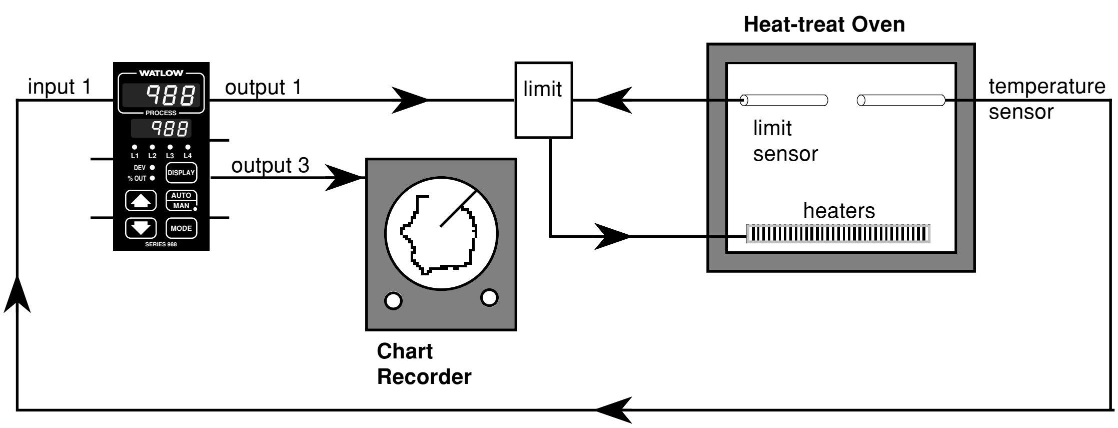
The retransmit output can be used to transmit an analog signal representing the value of either input process variable or the target set point variable. The retransmit signal is factory configured as either a milliamp or a voltage signal. In choosing the type of retransmit signal the operator must take into account the input impedance of the device to be retransmitted to and the required signal type, either voltage or milliamps.

Typically applications might use the retransmit option to record one of the variables with a chart recorder or to generate a set point for other controls in a multi-zone application (see page 3.11).

Requirements:

Output 3 is used for the retransmit option. Choose output type M (0-20, 4-20mA) or N (0-5, 1-5 or 0-10VDC), depending on the signal type. Select the output range in the Output menu.

Enhanced software is not required for this feature.



Sample Applications:

The 988 is being used to control the temperature of a heat-treat oven. The temperature of the process must be recorded on a chart recorder. The oven temperature range stays between 600 to 900 degrees F. The chart recorder requires a 4-20mA signal.

In the Output menu OtPt set analog output Aout to Prc1 to tag the input 1 process value as the parameter to be retransmitted. Set retransmit low limit ArL to 600 to set the low range for the retransmit signal to 600. Set retransmit high limit ArH to 900 to set the high range for the retransmit signal to 900. Set retransmit calibrate offset ACAL to 0, assuming there is no calibration offset required.

The retransmit output will be 4mA until the oven temperature is greater than 600 degrees F, at which point the signal will increase with temperature to 20mA at 900 degrees F and will not exceed 20mA.

Slidewire Feedback

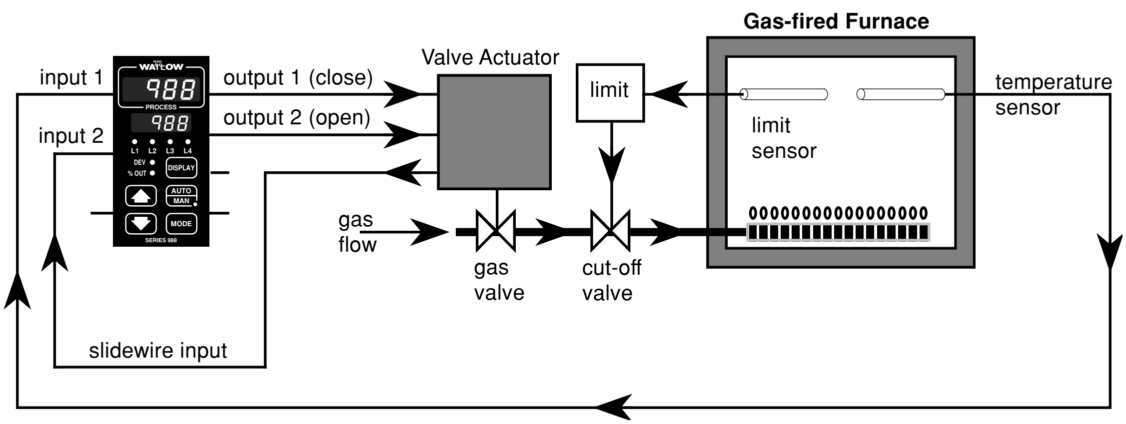
Overview

The 988 can control the position of a valve with a slidewire feedback position indicator. The 988 senses the resistance of the slidewire and compares it to the range low and range high settings to determine the valve position. The controller compares this to the percent output and takes action to match the two by opening or closing the valve.

Set the hunt Hunt parameter to limit valve hunting. The value is set for the percent of output (0.0 to 100.0). When the valve is within this dead band, a change in output greater than half the hunt parameter is required to trigger action. Output 1 responds to “close” commands and output 2 responds to “open” commands.

Requirements

A slidewire configuration uses at least two inputs and two control outputs. Input 2 must be a slidewire input. Outputs must be compatible with the slidewire valve actuators.



Sample Application

The 988 controls the gas valve for a gas-fired furnace to heat treat large metal parts. First the 988 must be “married” to the slidewire feedback from the valve actuator. To do this, first set the input 2 prompt In2 to slidewire SL id. Advance to the learn low resistance value prompt LrnL. Close the valve manually to the minimum resistance reading from the slidewire. Select YES in the upper display and press the MODE key to advance to the learn high resistance value prompt LrnH. Manually open the valve (maximum slidewire resistance). Select YES in the upper display and press the MODE key. At this point both the high and low resistance values have been learned and stored in the range low 2 rL2 and range high 2 rH2 prompts.

You can also manually set the range low and range high values. From the slidewire specifications, determine the low and high resistance values and enter these at the range low rL2 and range high rH2 prompts.

Once the control is operating, adjust the hunt Hunt parameter, to minimize valve oscillations. The hunt parameter sets up a dead band on both sides of the current valve position. The desired valve position is then compared to the actual position. If the difference is greater than the one-half of the hunt value, the 988 repositions the valve to achieve the temperature set point. Once repositioning is complete, the dead band is recalculated for the new valve position.

Chapter Four

Enhanced Software Features

Cascade	4.2
Differential	4.4
Dual PID sets	4.5
Duplex	4.6
Ratio	4.7

How to use this chapter:

This chapter describes the software features that are available in the 988 family of Watlow controllers equipped with the enhanced software option.

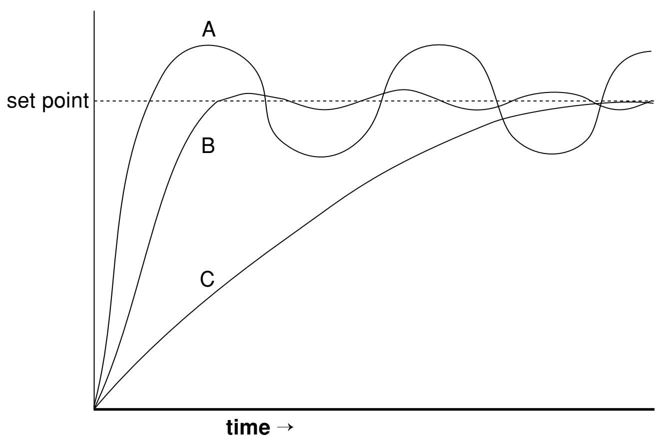
Cascade

Overview

Cascade control can handle a difficult process with minimal overshoot, while reaching the set point quickly. This minimizes damage to system components and allows for oversizing heaters for optimal heat-up rates.

Systems with long lag times between the energy source (heater, steam, etc.) and the measured process value cannot be controlled accurately or efficiently with a single control loop, because a lot of energy can build up before a response is detected. This can cause the system to overshoot the set point, which could damage the heater, product or heat transfer medium, such as a heat transfer fluid.

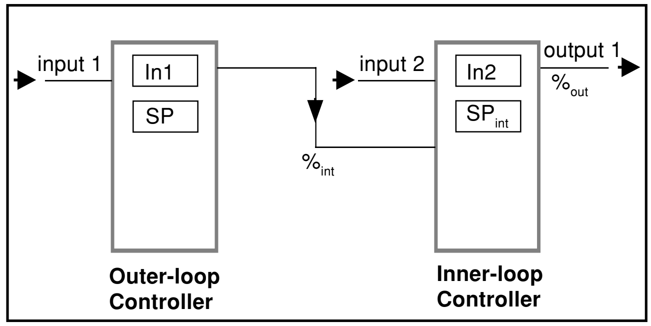
This graph illustrates a system with a long lag time. Curve A represents a single-control



system with PID parameters that allow a maximum heat-up rate. Too much energy is introduced and the set point is overshot. In most long-lag-time systems the process value may never settle out to an acceptable error. Curve C represents a single-control system tuned to minimize overshoot. This results in unacceptable heat-up rates, with the final value taking hours to reach. Curve B shows a cascade system that limits the energy introduced into the system, allowing an optimal heat-up rate with minimal overshoot.

This drawing shows two controllers configured as a cascade system. The second controller

Two controllers in one



The cascade feature allows the Series 988 to internalize the functions of two controllers

generates the internal set point. The Series 988 effectively combines both controllers into a single package.

The primary controller measures the process in the outer, or primary, loop with input 1 and compares the value to the desired set point. The difference between the set point and the process temperature generates an internal percent output value for the second controller. This value cannot be seen by the operator. This internal percent ($\%_{int}$) output generates the internal set point for the secondary, or inner loop. The secondary loop uses this set point and the value of input 2 (typically attached to the heater sheath) to control the heater temperature.

Algorithm

The following formulas show how the primary control sends a set point (based on input 2 range-high and range-low values) to the secondary control. The secondary control uses this set point (SP_{int}) to generate a percent output ($\%_{out}$) to the heater.

1.) $\%_{int}$ = PID Set A[In1 - SP]

2.) SP_{int} = (rH2 - rL2) * $\%_{int}$ + rL2

3.) $\%_{out}$ = PID Set B[In2 - SP_{int}]

The critical parameters are the range settings for input 2 of the second controller. The range-high value (rH2) is the maximum allowed set point for the secondary loop. The range-low value (rL2) is the minimum allowed set point.

In a system controlling a heater this would be the maximum and minimum desired sheath temperatures of the heater. Typically the range-low term is set below the ambient temperature. Otherwise the system could never fully cool down.

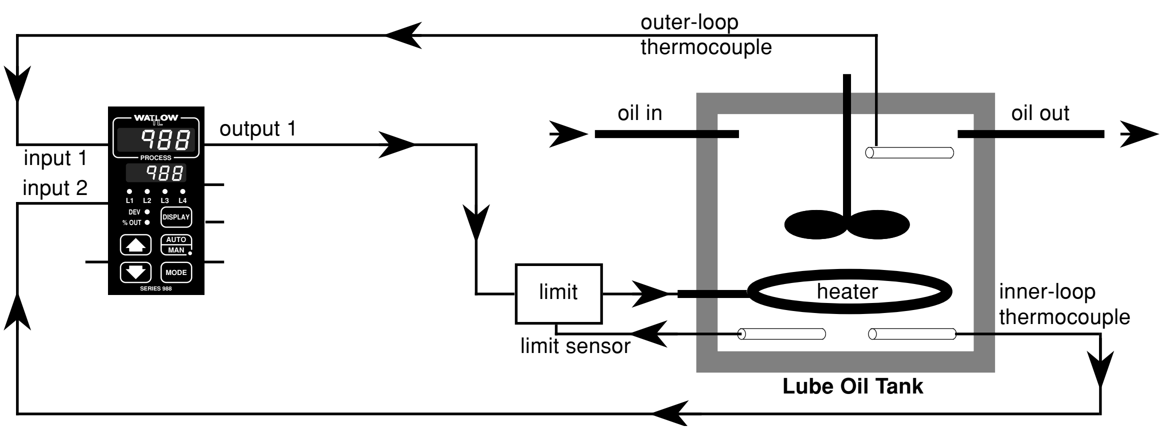
Setup

The PID parameters for the two PID sets, PID A and PID B, are determined with the auto-tune function. First the PID B settings (inner loop) are determined by setting the auto-tune prompt AUt to PID B P idb, which allows for tight control of the energy source at the set point determined by the primary loop. During the tuning process the internal percent ($\%_{int}$) value is determined by the auto-tune set point parameter AtSP. The default is 90%. This generates a set point for the heater equal to the range high times the AtSP value. The PID A settings (outer loop) are then determined by setting the auto-tune prompt AUt to PID A P idA. During the tuning process the set point is determined by multiplying the AtSP value by the set point (SP) entered via the front panel.

Once the system is stable the heater will operate at a value greater than the final process value (input 1). If this value is significantly different than the set point at which the secondary loop was tuned, adjust the AtSP parameter so that the tuning set point is near the value at which the heater is controlling.

Requirements

Cascade control requires enhanced software. Two analog inputs are required to monitor the inner and outer loops. At least one control output is required to control the process.



Sample Application

A Series 988 is used to heat lube oil to 125°F with a screw-plug-style heater. To protect the oil from breaking down and maximize its life, it is desirable to limit the maximum heater sheath temperature to 250° F.

The 988 is ordered with two thermocouple inputs. Input 2, the inner loop in the cascade configuration, measures the heater sheath. Input 1, the outer loop, measures the lube oil temperature before it leaves the tank. The external set point is 125°. By setting range high 2 rH2 to 250° the set point for the heater sheath will be limited, thus extending the lube oil life.

Differential

Overview

Differential control allows the Series 988 to control one process at a difference to another process. Input 2 acts as a remote set point input. However the displayed set point indicates the desired difference between input 1 and input 2. The set point to which input 1 will control to is determined by the equation:

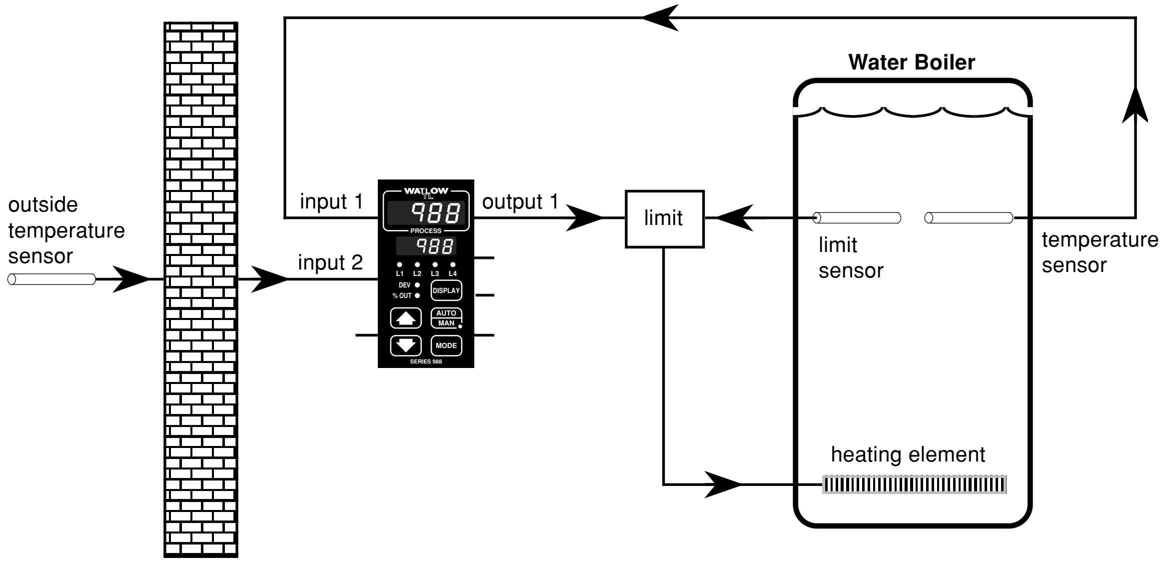
internal set point = input 2 + differential set point

The lower display shows the differential set point, which can be adjusted with the increment (up-arrow) and decrement (down-arrow) keys.

Please note that while in the differential control mode the set point for input 1 cannot be viewed and must be calculated with the equation.

Requirements

Two inputs and the enhanced software option are required.



Sample Application

The most common application using differential control is to maintain water temperature in a boiler at a differential to the outside air temperature. A thermocouple at input 2 senses the outside air temperature and adjusts the internal set point to maintain the boiler water temperature 120 degree higher. Substituting values we have: *boiler temperature = outside temperature + 120°.*

In this application the system uses two, type J thermocouples: one to sense boiler water temperature (input 1) and one to sense the outside air temperature (input 2).

To configure the controller, first enable input 2 (set In2 to J). To enable the differential control algorithm set the control prompt CntL in the Global menu to differential dIFF. Press the DISPLAY key. The lower display will read 0, indicating no differential between input 1 and input 2. Adjust the set point to 120. The internal set point for input 1 is now equal to the input 2 value plus 120, which will maintain the boiler water temperature 120 degrees higher than the outside air temperature.

Dual PID sets

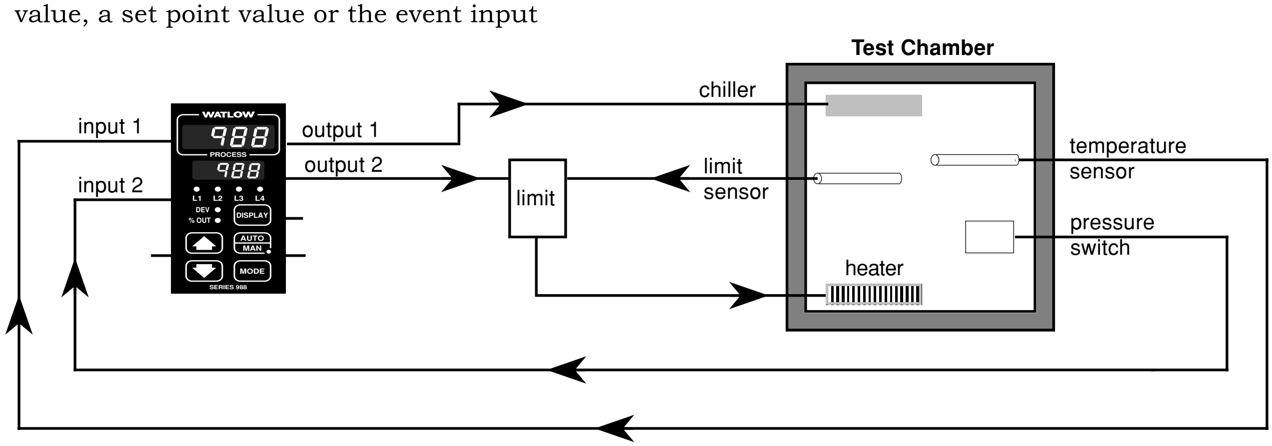
Overview:

Standard software units have a single set of PID parameters. Units with enhanced software can use two independent sets of heat/cool PID parameters, PID A P idA and PID B P idb. To enable dual PID, enter the Global menu and set the algorithm prompt ALgo to dual PID P id2. This second set of PID parameters enables the controller to switch between two sets of PIDs, to compensate for changes in the system characteristics. This need can arise from a variety of circumstances, such as significant set point changes (controlling at 250, then controlling at 750), operating a furnace with half a load versus a full load of steel, changing the speed of a conveyor through a curing oven or using different materials in an extruder.

The 988 family can be configured to switch between PID A and PID B based on a process value, a set point value or the event input status. Use the dual PID P id2 prompt in the Global menu, to select what will cause the switch: process Proc; set point StPt; or none no. If process Proc is selected at the P id2 prompt, the PID's will switch based on the crossover process value. If set point StPt is selected at P id2, the PIDs will switch at the crossover set point value, PID A used below the crossover point and PID B above. PID crossover can also be selected via event input by selecting P id at the E i1 or E i2 prompt. PID A is used when the event input switch is open, PID B when closed. (Note : One event input is standard on all units, a second event input is an option)

Requirements:

The 988 family controller needs the enhanced software option to use dual PID sets.



Sample Application:

A test engineer needs to control the temperature in a test chamber that can be operated at normal atmosphere or under vacuum conditions. If he tunes the controller for normal atmospheric conditions, when he reaches the portion of his test that requires a vacuum, he must stop the test and enter new PID parameters to maintain stable temperatures. The system characteristics are so very different, that one set of PID's will not give satisfactory results under both normal and vacuum conditions.

The 988 solves this problem with the dual PID option. Auto-tuning PID A under normal atmospheric conditions, then auto-tuning PID B under vacuum conditions, establishes PID values for two sets of system characteristics. A pressure switch connected to the event input tells the controller when to switch between PID A and PID B, eliminating the need to change PID values manually.

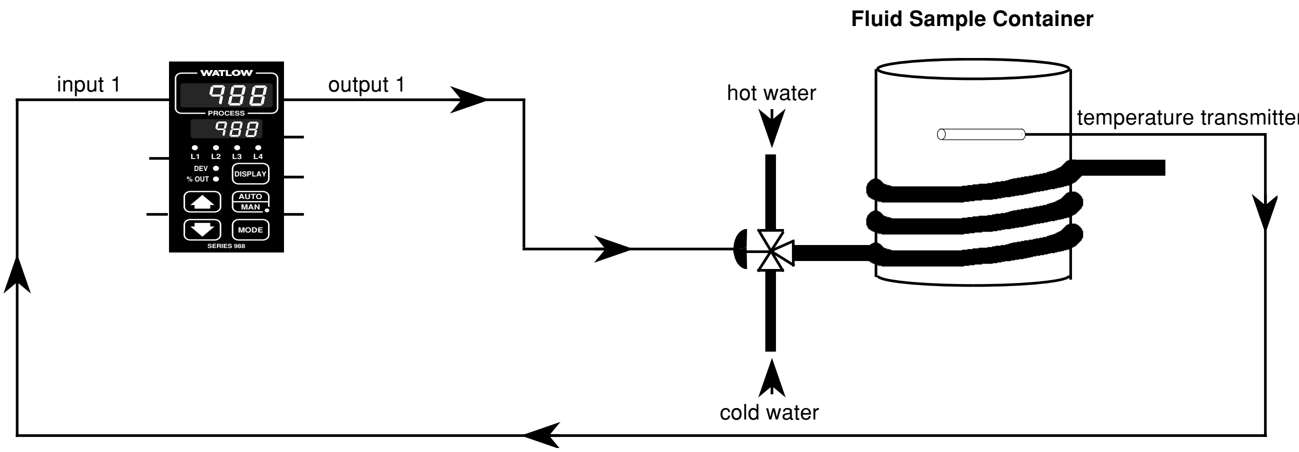
Duplex

Overview

Certain systems require that a single process output control both heating and cooling outputs. A Series 988 controller configured with enhanced software and a process output can function as two separate outputs. With a 4 to 20mA output the heating output will operate from 12 to 20mA (0 to +100 percent) and the cooling output will operate from 12 to 4mA (0 to -100 percent). In some cases this type of output is required by the device that the 988 controls, such as a three-way valve that opens one way with a 12 to 20mA signal and opens the other way with a 4 to 12mA signal. This feature reduces the overall system cost by using a single output to act as two outputs.

Requirements

The duplex control feature requires the enhanced software and a process output. Duplex applications require a special valve.



Sample Application

The system outlined below uses a three-way valve for heating and cooling a fluid sample. Coils surround the container holding the fluid. When the temperature needs to be raised, the signal to the valve will be between 12 and 20mA, sending hot water through the coils. When cooling is required, the signal will be between 12 and 4mA, sending cold water through the coils.

Ratio

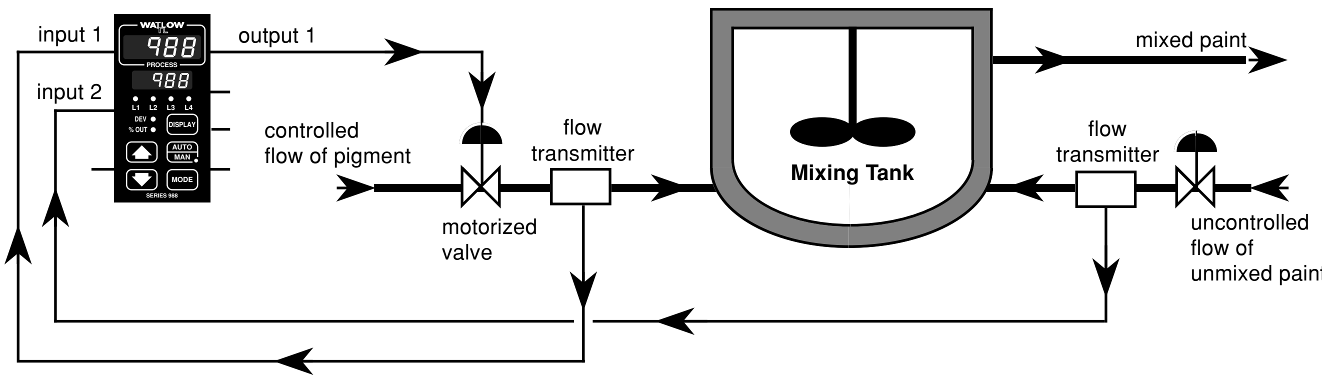
Overview

This feature allows the 988 to control one process as a ratio of another process. This is especially useful in applications that mix two materials, whether steam, paint or food ingredients.

Input 2 of the 988 measures the part of the process that is either uncontrolled or controlled by another device. The part of the process controlled by the 988 will be maintained at a level equal to the quantity measured at input 2 multiplied by the ratio term set by the user. Input 1 monitors the controlled part of the process.

Requirements

Ratio control requires enhanced software. Two analog inputs are required to monitor the process, and at least one output adjusts the controlled part of the process.



Sample Application

Blue pigment must be added to paint at a ratio of one part per 100 to create a mixed paint of the desired color. The uncolored paint flows into the mixer in an uncontrolled stream that is set manually and sensed by input 2. A motorized valve controls the flow of pigment, which is monitored by the flow sensor to input 1. The flow rate of the uncolored paint determines the set point for the motorized valve that controls the pigment flow. If an operator needs to change the rate of flow for the uncolored paint, the set point will shift accordingly to maintain the correct ratio in the mixing tank.

The application engineer set up this feature in software by choosing ratio rAti as the control CntL parameter in the Global menu. The set point value displayed was then a ratio value. He entered 0.01 to maintain an input 1:input 2 ratio of 1:100.

Chapter Five

Standard Features

Alarms	5.2
Auto/Manual	5.4
Diagnostics	5.5
Input errors	5.6
Lockout	5.7
Transmitter power supply	5.8

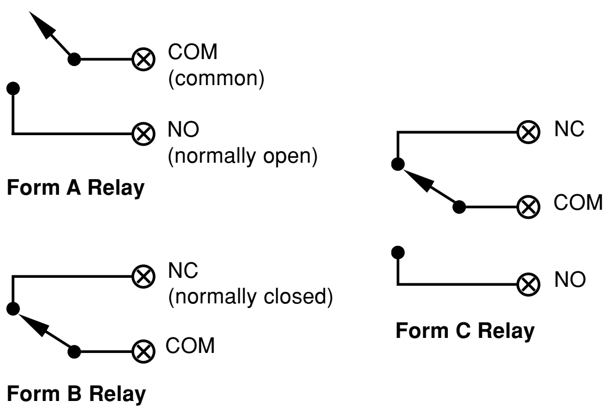
How to use this chapter:

This chapter describes features that, with the exception of transmitter power supply, are included in every controller in Watlow's Series 988 family.

Alarms

Overview

Outputs 2, 3 and 4 can be configured as alarms. To configure an alarm the operator makes several decisions. First we'll show the difference between a form A, B and C relay.



The relays are shown in the "shelf state," with no power applied. Note that the form C option allows the operator to configure it as either a form A or a form B output. For the purposes of this discussion we will use the form C version, available in outputs 2 and 4 (Output 3 is selected, via a hardware jumper, as either a form A output or a form B output).

You need to make five decisions to configure an alarm output. In the following explanations only output 2 will be configured:

1-Output Type Ot2

First, choose the type of alarm: either normally energized AL2 or normally de-energized AL2n. This means that when there is no alarm condition, the alarm output is energized if normally energized AL2 is selected and de-energized if normally de-energized AL2n is selected.

Example: With normally energized AL2 selected for output 2 the output will be energized in the non-alarm state. Therefore the normally closed (NC) contact will be open.

2-Alarm Type AL2

This prompt allows you to select which input variable will trigger the alarm and whether the alarm is a deviation, process or rate alarm. Selecting process 1 Pr1 or deviation 1 dE1 references the input 1 value against the alarm 2 low A2LO and alarm 2 high A2HI settings. Selecting process 2 Pr2 or deviation 2 dE2 references the input 2 value against the alarm 2 low A2LO and alarm 2 high A2HI settings. Input 2 hardware must be connected and enabled.

Selecting rate rAtE references the rate of change of the input 1 value in degrees per minute. A2LO defines a negative rate and A2HI defines a positive rate of change limit.

A process alarm sets an absolute process value independent of the set point. When the process exceeds that value an alarm occurs. The process value is independent of the set point.

A deviation alarm alerts the operator when the process strays too far from the set point. The operator can enter both high and low alarm settings referenced to the set point. A change in set point causes a corresponding shift in the deviation alarm. Low alarms are set at a negative deviation, and high alarms are set at a positive deviation.

3-Hysteresis HYS2

This selects the switching hysteresis for the alarm. Once an alarm has occurred it will not clear until the process value is above the alarm-low setting or below the alarm-high settings by a margin equal to the hysteresis.

Example: An alarm starts when the process value reaches the alarm high setting. The alarm will not clear until it is below the high setting by an amount equal to or greater than the alarm hysteresis.

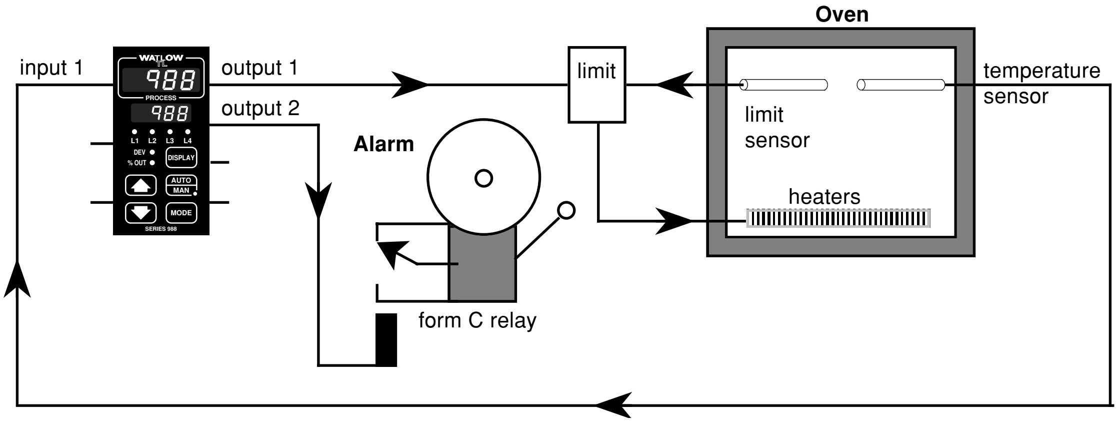
4-Latching LAt2

Alarms can be latching or non-latching. When the alarm condition is removed, a non-latching alarm automatically clears the alarm output and alarm message, if one is present. You must manually clear a latched alarm by pressing the AUTO/MAN key once.

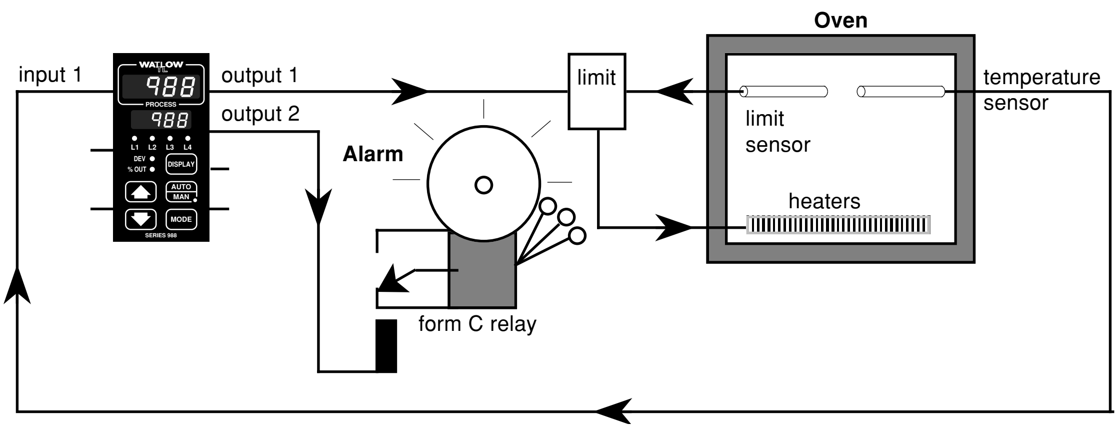
Standard Features

5-Silencing SIL2

Alarm silencing overrides the alarm at power up, and it allows the operator to silence an alarm with the system still in an alarm condition. The silencing is active until the process has entered the safe region located between the low and high alarm settings. Any future deviation outside the safe region triggers an alarm. If the alarm occurs at this point, the output can be silenced by pressing the AUTO/MAN key once, but the alarm message is still displayed.



The temperature is within the normal range.
Output 2 is inactive.



An over-temperature condition activates output 2, which turns the alarm on.

Sample Application

An operator is using a deviation alarm to keep a process within +/- 5°F of the set point. Output 2 is set up as a deviation alarm that activates a buzzer. However, when the process powers up in the morning, the process temperature is below the low deviation alarm set point, causing the buzzer to sound until the process reaches the low alarm set point. Selecting ON On at the silencing prompt SIL2 in the Output menu, disables the alarm output controlling the buzzer until the process gets within the deviation alarm set points. It also allows the operator to silence the buzzer by pressing the AUTO/MAN key once, if an alarm does occur.

Auto/Manual

Overview:

When it operates automatically the controller uses an input signal (from a thermocouple, RTD, transmitter, etc.) to determine how best to adjust the output power level to match a set point. This constant monitoring of process variables and the corresponding adjustments in the output power level is referred to as closed-loop control. This is the normal mode of operation for most applications.

Manual operation does not use feedback from the input signal to determine a power level. The power level must be adjusted manually by the operator. The controller may or may not be monitoring the process variable. This open-loop control is used for applications in which closed-loop control is not desired, for instance as a diagnostic tool or when the controller detects a sensor break (see Input Errors, page 5.6).

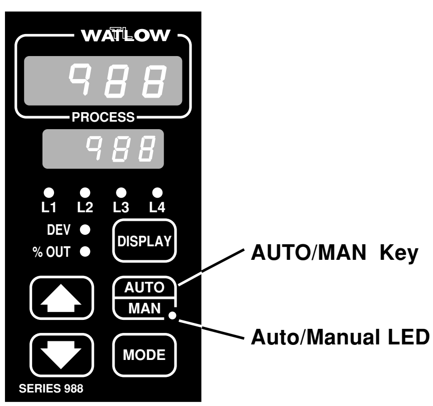
Manual operation provides open-loop control of the outputs from a range of -100 percent to +100 percent power (-100 percent for full cool, +100 percent for full heat). The Series 988 controller allows a negative output value only if one of the control outputs is configured for cool.

If the LED in the corner of the AUTO/MAN key is off, the controller is in the automatic mode and the bottom display is a set point value in degrees or units. If the LED is on, the controller is in the manual mode, and the bottom display indicates the percent power output.

To toggle between auto and manual operation, press the AUTO/MAN key twice. When you press the AUTO/MAN key once, the LED in the lower right hand corner of the AUTO/MAN key, begins to flash. To complete the change, press the AUTO/MAN key again while the LED is flashing. The transition from automatic to manual is a “bumpless transfer,” the control will switch to manual mode maintaining the last power level it used in automatic mode.

Requirements:

Automatic/manual operation is a standard feature on all units.



Sample Application:

An engineer has a process that needs to be brought on-line at a low power level, until a predetermined process value is achieved. At this point, the controller can be allowed to take control of the output power level. Utilizing the automatic/manual function, the engineer manipulates the power level in manual mode until it is safe to allow the controller to take control. At that point, he switches the 988 to the automatic mode, letting the controller maintain the output power level.

Diagnostics

Overview:

The Series 988 Diagnostics menu allows you to read the software revision, ship date, hardware configuration and ambient temperature without removing power from the control.

To access the Diagnostics menu press the increment (up-arrow) and decrement (down-arrow) keys simultaneously for six seconds. The factory prompt FctY appears in the lower display and panel lockout prompt PLOC in the upper display. Press the increment key until diagnosis dIAG appears in the upper display. Then press the MODE key.

The list below explains the menu prompts:

dAtE Date provides the date of the final control test. The first two numbers indicate the week (01 through 52) and the last two show the year.

SOFt Soft signifies the control software revision.

Sn-- ---- The serial number follows “Sn” in the upper display. The six-digit number begins with the last two digits in the upper display and wraps around to the lower display.

AMb Ambient temperature indicates the temperature at the input 1 terminals, in degrees F.

Acnt Ambient counts is for factory use only.

Gnd Ground counts is for factory use only.

cnt1 Input 1 counts is for factory use only.

cnt2 Input 2 counts is for factory use only.

Depending on the modules installed and the DIP switch settings, some of the following input and output type displays will appear:

Types for Inputs 1 ItY1 and 2 ItY2

- nonE no module
- tc thermocouple only
- Curr current detect
- SLId slidewire
- UOFF universal OFF
- Urtd universal RTD
- Utch universal tc high gain
- UtcL universal tc low gain
- UMu universal millivolts
- UPrc universal process
- EI2 event input 2

Types for Outputs 1 OtY1 through 4 OtY4

- nonE no module
- SSr1 0.5A SSR
- SS1S 0.5A SSR w/ suppression
- SSr2 2.0A SSR
- dc switched DC
- rLYC form C relay
- rLCS form C relay w/ suppression
- rLAb form A/B Relay
- Proc process
- UrEt voltage retransmit
- IrEt current retransmit
- SPLY power supply
- 232 RS-232 communications
- 485 EIA-485/422 communications

dISP Display tests each display and LED. If any display or LED is absent contact the factory.

tout The test output prompt can be used to activate the available outputs on the unit, with the exception of process outputs, transmitter power supply or communications output. To select an output, use the increment or decrement key to advance from OFF OFF to the desired output (output 1 active out1 through output 4 active out4). After three seconds the corresponding load LED will light and the output will be energized. This output will remain energized until you select another output or off, or exit the Diagnostic menu.

OPLP The open loop prompt enables the open-loop error function. The error message open loop OPLP flashes in the lower display when ON On is selected and a heat or cool output is full on and no temperature change has occurred over a period of time, based on system characteristics. This prompt only functions in the proportional control mode.

Requirements:

The Diagnostics menu is a standard feature on all Series 988 controllers. When asking the factory for technical assistance, have the information from the above prompts on hand. All prompts in this menu are read only.

Sample Application:

An engineer needed to figure out why an oven was malfunctioning. She used test output tout to force ON output 1 out1, which controlled the heaters. A quick check with a meter revealed a burned out heater element.

Input Errors

Overview

When the 988 receives input information it cannot interpret or finds a problem with one of its internal functions, it generates an error code to help identify the problem. The controller switches to manual mode and operates at a fixed power output level, depending upon the type of error code and the selections made in the Global menu.

If an input related error occurs, four dashes ---- appear in the upper display and the bottom display indicates the output power level. Press the AUTO/MAN key once to display the error code in the upper display for five seconds.

The failure mode prompt FAIL determines what the 988 output power level will be when an input error occurs. The bumpless transfer bPLS selection allows the 988 to switch from automatic to manual mode at the percent power level the controller was at when the input error occurred. However, certain conditions must be met: the process must have stabilized at a power level between -70 percent and +70 percent, with no more than plus or minus five percent variation for two minutes prior to the sensor break. If these conditions have been met, the 988 switches to manual mode at that last stable power level. If not, the 988 transfers to manual mode with no power output.

Preselect a power level at the failure mode prompt FAIL with the increment (up-arrow) and decrement (down-arrow) keys. If the unit is configured for heat only, the fail power level is adjustable from 0 (off) to 100 percent (full heat). If it controls heat and cool outputs, the power level is adjustable from -100 (full cool) to +100 percent (full heat).

If the error code is related to internal functions of the 988 (Er5 or Er9), the controller:
* remains in auto mode with both control outputs off;
* switches all alarm outputs to the shelf state (power OFF);
* lower display is blank and the upper display indicates the error code;
* keys are all inactive.

The above conditions will occur regardless of which menu is active at the time or what failure mode value was selected. If Er5 occurs, all Setup menu parameters will return to factory default values. To clear any one of these errors, turn the 988 OFF for a few seconds then turn it back ON. If the error remains, contact the factory.

Series 988 error codes

E1 1 input 1 E2 1 input 2 A/D underflow error
E1 2 input 1 E2 2 input 2 sensor under-range error
E1 3 input 1 E2 3 input 2 sensor over-range error
E1 4 input 1 E2 4 input 2 A/D overflow error

Er5 non-volatile checksum error
Er9 configuration error

Sample Application

An engineer has many applications throughout his plant requiring controllers. He wants to know what the controller will do if the sensor fails. In some of his processes, for instance a gas valve, the outputs must go full OFF (0 percent), others, such as a valve controlling water to a cooling jacket, should go to full open (-100 percent), while others need the outputs to go to an intermediate power level. With the 988 the user can determine what the output will do if a sensor fails.

Lockout

Overview:

An array of hardware and software lockout features gives you tremendous flexibility in configuring various levels of user access. The Factory FCtY and Setup SEt menus can be locked out by setting a DIP switch behind the panel. Four levels of lockout can be set from the front panel. A simple switch or a keylock switch can be connected to a digital event input to lock or unlock access to the front panel.

The 988 leaves the factory with DIP switch 2 in the off position, allowing access to the Setup and Factory menus.

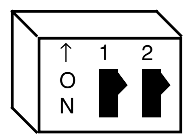
The front panel can be locked out via digital events at input 2 or 3. This lockout function is enabled by selecting lock LOC under an event input prompt (E i1 or E i2) in the Global menu.

The software lockout functions appear under the Factory prompt, in the Panel Lockout PLOC menu. For each menu, one of three lockout levels can be selected. Full lockout FULL does not allow the selected menu to be viewed or altered. Read only rEAd allows a menu to be viewed but not altered. No lockout nonE allows the selected menu to be viewed and changed.

The lock prompt LOC allows the operator to select several levels of front-panel lockout:
LOC = 0 enables all keys
LOC = 1 disables the MODE key
LOC = 2 disables MODE and AUTO/MAN keys
LOC = 3 disables all keys except the increment+decrement combination

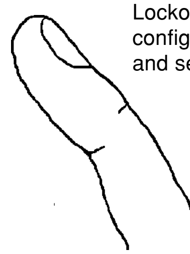
Requirements:

All 988 Family controllers are equipped with software and hardware lockout features.



You can lockout the Setup and Factory menus with a DIP switch behind the front panel.

You can lock out the front panel with the digital event input.



Lockout menus let you configure access to menus and settings.

Sample Application:

During the initial configuration and start-up an engineer will need access to all the parameters. Once the process is configured, he will give the operator access to only the process and alarm set points. Security is also an issue, and he wants only authorized operators to have access to these parameters.

The Panel Lockout PLOC menu gives him access to all parameters during the start-up. Once the process is online, all Panel lockout menus except System are set to full lockout FULL. The System menu is set to no lockout nonE, giving the operator access to the alarm set points. Process security is achieved with a keylock switch connected to event input 2. Event input 2 E i2 in the Global menu, is set to lock LOC. Without a key, nothing is accessible from the front panel. With a key, process and alarm set points are accessible.

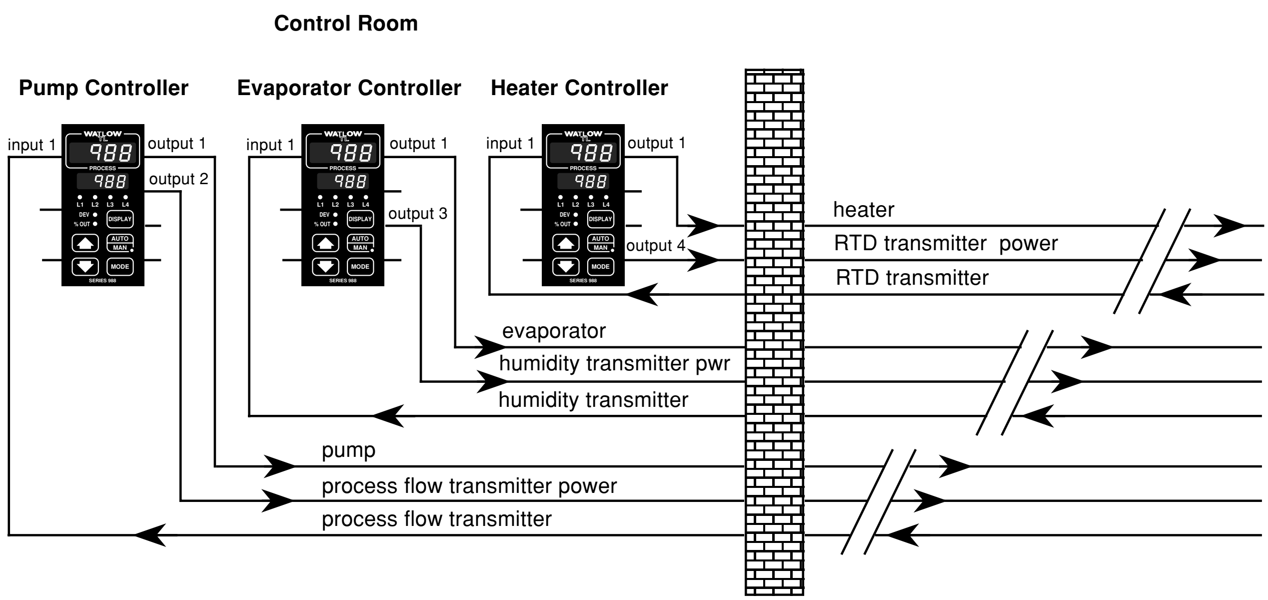
Transmitter Power Supply

Overview

In an electrically noisy environment or when you have to use a long sensor lead, you may need to use a transmitter to convert the sensor signal to a 4-20mA signal. Normally you would have to buy and install a separate power supply for the transmitter or for other signal conditioning devices, but you can order a Series 988 with a 30mA power supply as one of its outputs. The factory sets the power supply voltage to 20VDC, but you can use DIP switches to change it to 5 or 12VDC as well.

Requirements

A transmitter power supply can be ordered for output 2, 3 or 4.



Sample Application

An engineer at a food processing plant needs to control several processes from a central control room, which is more than 100 feet away from some of the machines being controlled. Because of the distance and the noisy electrical environment, thermocouples cannot provide dependable readings.

The engineer has installed several Series 988 controllers with power supplies matched to a variety of transducers. DIP switch settings configure the output voltages for 5, 12 or 20VDC.

Chapter Six

Specifications

Input Table	6.2
Output Table	6.3
Dimensions	6.4
Displays and Keys Chart	6.5
Setup Requirements	6.6
User's Manual	6.7
Product Specification	6.8
Warranty	6.9

How to use this chapter:

This chapter contains charts and lists describing specifications of the Watlow's 988 family of controllers.

Specifications

Input Table

988 FAMILY INPUT TYPES	Input 1	Input 2	Input 3
0-none			
1-basic signal conditioner type: J, K, T, N, C, D, Pt 2 high temperature moderate sensor accuracy and stability low and high range low sensor cost			
2-universal signal conditioner **process input** 0-5VDC, 1-5VDC, 0-10VDC, 0-50mVDC, 0-100mVDC, 0-20mA, 4-20mA non-thermal applications sensor determines accuracy and stability long leads of transducer output low and high range best sensor noise immunity moderate to high sensor cost **resistance temperature detector (RTD)** 100-ohm platinum type: 1° JIS or DIN, 0.1° JIS or DIN high sensor accuracy and stability low range, moderate sensor cost **thermocouple** type: J, K, T, N, R, S, B, C, D, Pt 2 high temperature moderate sensor accuracy and stability low and high range low sensor cost			
3-slidewire feedback 0- to 1200-ohm range determines valve position sensor determines accuracy and stability moderate sensor cost			
4-heater current transformer 50mA transformer secondary maximum reads heater current moderate sensor accuracy and stability additional ranges may be available moderate sensor costs			
5-digital event dry switch or DC volts input 0-3VDC (open) to 14-36VDC (closed) input 2 0-3VDC (closed) to 14-36VDC (open) input 3 no to low cost			

option available if shaded

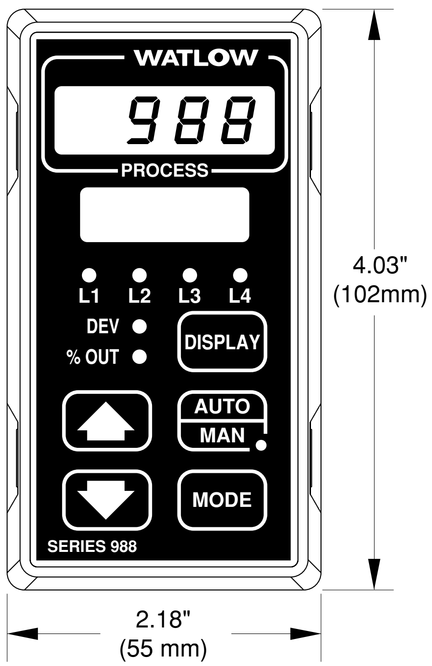
Output Table

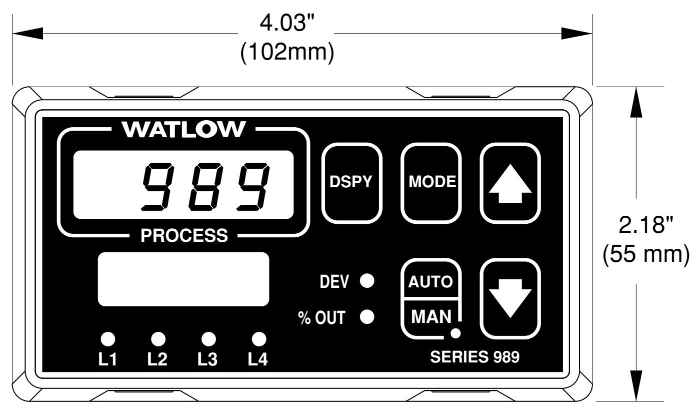
988-FAMILY OUTPUT TYPES	Output 1	Output 2	Output 3	Output 4
none A				
solid-state relay good life/low cost **B**- 0.5A, w RC suppression **K**- 0.5A, w/o RC suppression				
open collector best life/low cost **C**- switched DC				
electromechanical relay shortest life/high cost (w maintenance) **D**- form C, 5A, w RC suppression **E**- form C, 5A, w/o RC suppression				
electromechanical relay shortest life/high cost (w maintenance) **J**- form A or B, 5A, w/o RC suppression				
universal process types best life/low cost **F**- 0-5VDC, 1-5VDC, 0-10VDC, 0-20mA, 4-20mA				
transmitter power supply **T**- 5, 12, 20VDC @ 30mA				
process retransmit chart recorder or data-logging device **M**- 0-20mA, 4-20mA **N**- 0-5VDC, 1-5VDC, 0-10VDC				
communications with a computer **R**- RS-232 **S**- EIA-485, RS-422				

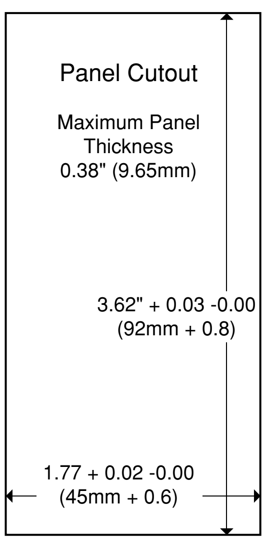
option available if shaded

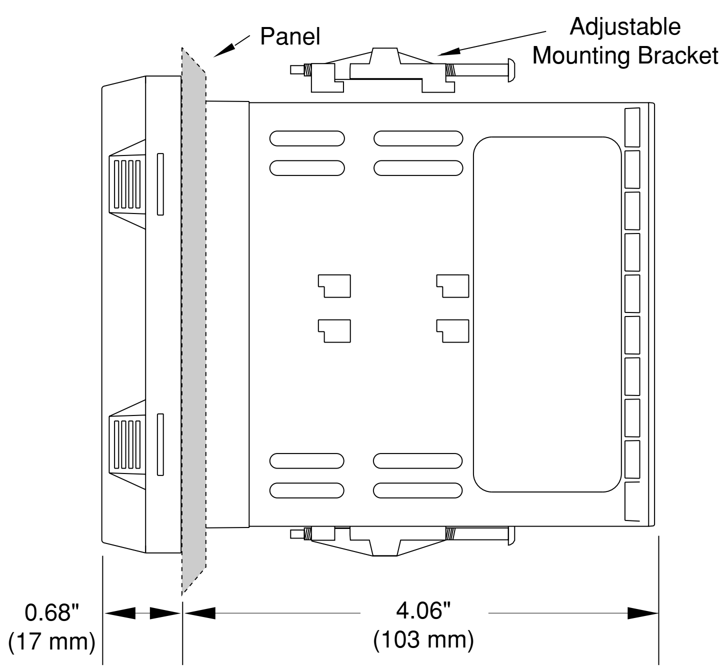
Specifications

Dimensions









Note: A minimum of 1.66 inches (42.2 mm) spacing between panel cutouts is recommended.

Specifications

Displays and Keys Chart

Upper Display
Reads actual process value or operating paramenter value or error code — red or green.

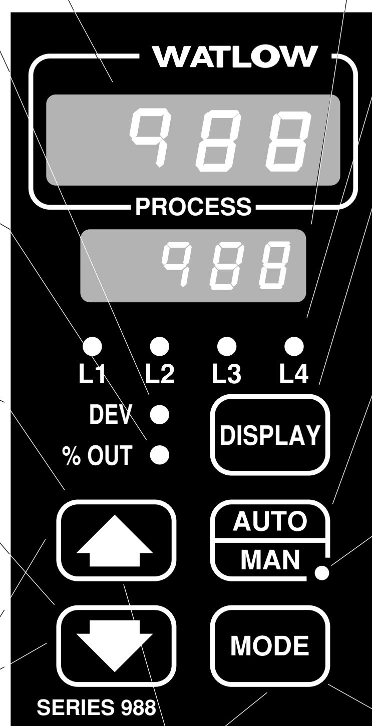
DEV (Deviation) LED
Indicates that the lower display now reads a deviation-from-the-set-point value.

% OUT (percent output) LED
Indicates that the lower display now reads the percent-output value.

Increment (up-arrow) Key
Increases the value or changes the selection in the upper display.

Decrement (down-arrow) Key
Decreases the value or changes the selection in the upper display.

Incr. + Decr. Combination
Press for three seconds to reach the Setup menu; press for three more seconds to reach the Calibration menu.



MODE + Incr. Combination
Press to move backwards through prompts in a menu. Press and hold the MODE key and use the increment key to move backwards until you reach the top of the menu.

Lower Display
Reads Display Loop information, menu or prompt names, or alarm codes — red or green hardware.

L1, L2, L3, L4 LEDs
Shows the active output(s).

DISPLAY Key
Takes the control "home" to the Display Loop (current process values and set point information) from any menu location.

AUTO/MAN Key
Clears or silences alarms with one press, or toggles between Auto and Manual control with two presses.

AUTO/MAN LED
Indicates Manual control; or, when blinking, indicates that another press will toggle control state.

MODE Key
Steps through the menus. In Auto control, enters data selected less than five seconds previously.

Setup Requirements

Controllers from the Series 988 family require six steps to set up — from system design to system operation.

1 — Build the Part Number
This booklet helps with the first step, selecting the features your application will need. The features are recorded in a part number, which Watlow uses to custom build each controller.

2 — Set the DIP Switches
The *Series 988/989 User's Manual* explains how to set the DIP switches inside the controller chassis. You can set DIP switches to lock out the Factory and Setup menus. Other DIP switches allow you to select some of the input, output and power needs of your application.

3 — Mount and Wire the Controller
The *Series 988/989 User's Manual* clearly explains and illustrates the process of correctly mounting and wiring your controller.

4 — Configure the Controller for Your Application
The next step involves determining settings and values, then entering them from the front panel of the 988. Chapter Seven of this book will help you chose the software and parameters to best control your application. The *Series 988/989 User's Manual* will guide you through the menus and prompts you will use to configure the controller's software.

5 — Startup and System Operation
For the final setup step carefully review the previous steps, then turn on the system. Some parameters, such as slidewire feedback, can be auto-tuned after startup. Then system performance and alarms should be thoroughly tested.

6 — Documentation
Once the system is operating corrcctly, make photocopies of the menu flow diagrams in the user's manual and document all your settings.

User's Manual

The *Series 988/989 User's Manual* provides the information you will need to install, wire, configure and operate the Series 988 controller, in most applications. Detailed drawings illustrate DIP switch settings, panel mounting and proper wiring of the 988. Easy to use charts and instructions explain how to use the menus and prompts to configure the 988 to your application.

A communications manual and a calibration manual are also available for the Series 988.

Product Specifications

Control Mode
- •Dual input, quad output, optional retransmit of set point or process variable.
- •Programmable direct and reverse acting control outputs.
- •One step auto-tuning.

Operator Interface
- •Local/Remote set point capability.
- •Dual, 4-digit LED displays. Upper: 0.4" (10mm), Lower: 0.3" (8mm).
- •Mode, Auto/Man, Display, Up and Down keys.

Input
- •Contact input for software function select.
- •Type J, K, T, N, C(W5), D(W3), E, R, S, B, Pt 2 thermocouple, 100Ω platinum 1° or 0.1° RTD, or 0-50mV, 0-100mV, 0-20mA, 4-20mA, 0-5VDC, 1-5VDC, 0-10VDC, slidewire, digital event input or heater current options.
- •Sensor break protection de-energizes control output to protect system or selectable bumpless transfer to manual operation. Latching or non-latching.
- •°F or °C display or process units, user selectable.

Sensor Ranges

J t/c:	32	to	1500°F	or	0	to	816°C
K t/c:	-328	to	2500°F	or	-200	to	1371°C
T t/c:	-328	to	750°F	or	-200	to	399°C
N t/c:	32	to	2372°F	or	0	to	1300°C
R t/c:	32	to	3200°F	or	0	to	1760°C
S t/c:	32	to	3200°F	or	0	to	1760°C
B t/c:	1598	to	3300°F	or	870	to	1816°C
E t/c:	-328	to	1470°F	or	-200	to	799°C
C t/c:	32	to	4200°F	or	0	to	2316°C
D t/c:	32	to	4200°F	or	0	to	2316°C
Pt 2:	32	to	2543°F	or	0	to	1395°C
1°RTD (JIS):	-328	to	1166°F	or	-200	to	630°C
1°RTD (DIN):	-328	to	1472°F	or	-200	to	800°C
0.1°RTD (JIS and DIN):	-99.9	to	999.9°F	or	-73.3	to	537.7°C
0-5VDC:	-999	to	9999				
1-5VDC:	-999	to	9999				
0-10VDC:	-999	to	9999				
0-20mA:	-999	to	9999				
4-20mA:	-999	to	9999				
0-50mVDC:	-999	to	9999				
0-100mVDC:	-999	to	9999				
Slidewire:	100	to	1200Ω				
Current:	0	to	50mA				
Potentiometer:	0	to	1200Ω				

Output Options
- •Solid state relay, 0.5A @ 24VAC min., 253VAC max., opto-isolated, zero cross switching. With or without contact suppression.
- •Open collector, switched DC signal provides a minimum turn ON voltage of 3VDC into a minimum 500Ω load; maximum ON voltage not greater than 32VDC into an infinite load.
- •Electromechanical relay*, Form C, 5A @ 120/240VAC, 6A @ 28VDC, 1/8 hp. @ 120VAC, 125VA @ 120VAC. With or without contact suppression.
- •Process, 0-20mA, 4-20mA, 0-5VDC, 1-5VDC, or 0-10VDC.
- •Electromechanical relay*, Form A/B, 5A @ 120/240VAC, 6A @ 28VDC, 1/8 hp. @ 120VAC, 125VA @ 120VAC. Without contact suppression.
- •External transmitter power supply, 5V ±5% @ 30mA, 12V ±5% @ 30mA, or 20V ±5% @ 30mA.
- •RS-232 communications or EIA-485/RS-422 communications, opto-isolated.

Accuracy
- •Calibration accuracy & sensor conformity: ± 0.1% of span, ±1 LSD, 77°F ± 5°F (25°C ± 3°C) ambient & rated line voltage ±10%.
- •Accuracy span: 1000°F/540°C minimum.
- •Temperature stability: ± 0.2°F/°F (0.1°C/°C) change in ambient.
- •Voltage stability: (± 0.01% of span) / (% of rated line voltage).

Agency Approvals
- •UL873 and UL508, File #E43684; CSA pending; NEMA 4X.

Terminals
- •#6 compression universal head screws, accepts 20-14 gauge wire.

Power
- •100 - 240VAC +10%/-15%, 50/60Hz, ± 5%.
- •16VA maximum.
- •Data retention upon power failure via non-volatile memory.

Operating Environment
- •32 to 149°F (0 to 65°C), 0 to 90% relative humidity, non-condensing.

* Electromechanical relays are not recommended for PID control. They are warranted for only 100,000 contact closures.

Warranty

The Watlow Series 988 family of controllers is warranted to be free of defects in material and workmanship for 36 months after delivery to the first purchaser for use, providing that the units have not been misapplied. Since Watlow has no control over their use, and sometimes misuse, we cannot guarantee against failure. Watlow's obligations hereunder, at Watlow's option, are limited to replacement, repair or refund of purchase price, and parts which upon examination prove to be defective within the warranty period specified. This warranty does not apply to damage resulting from transportation, alteration, misuse or abuse.

Chapter Seven

How to Choose the Right 988 to Fit Your Application

Overview	7.2
Input	7.3
Output	7.4
Software	7.5
Standard Features	7.6
Hardware	7.7
Review and Optimize	7.8
Faxable System Description	7.10
Model Number Information	7.11

How to use this chapter:

The Watlow 988 family of controllers can be used in an almost infinite variety of applications, in part because the inputs, outputs and many other attributes can be factory configured to match the requirements of many different processes. A controller's model number contains this factory configuration information. This chapter will guide you through the process of optimizing your application with a Series 988 controller and determining the correct model number.

Make one or more copies of the worksheet on page 7.10 and any other pages you want to write on. Then sit down with scratch paper and a pencil and carefully work through the steps to determine the best configuration for your application. Use the "Helpful References" listed in the left column of each page.

When you finish, you will have a completed diagram showing how your application can be controlled by a Series 988 controller and a model number for the proper controller configuration.

Experts who are familiar with the Series 988 controller may want to go directly to the Faxable System Description on page 7.10.

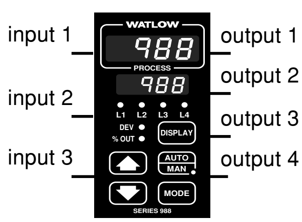
How to Choose the Right 988 to Fit Your Application

Step 1: Overview

HELPFUL REFERENCES

Chapter 1, Test Drives, provides diagrams and explanations of several different types of applications.

Chapter 2, Basic Control Strategies and Terms, explains the basic concepts and vocabulary of control applications.



A. Describe the process that the 988 will control.

B. What raw materials go into the process?

C. What product does the process create?

D. List the sensors, switches and controls used in the process.

E. List the heaters, motors, valves and other devices used in the process.

F. List ambient conditions, performance requirements and safety concerns involving the process.

G. Make a rough sketch of the process including all of the elements listed above. Be sure to label all of the parts.

Step 2: Input

HELPFUL REFERENCES

Use the complete input table in Chapter 6, Specifications.

See the filled in worksheets in Chapter 1, Test Drives.

	Inputs 1	2	3
0-none			
1-basic signal conditioner			
2-universal signal conditioner process input resistance temp. detector thermocouple			
3-slidewire feedback			
4-heater current transformer			
5-digital event			

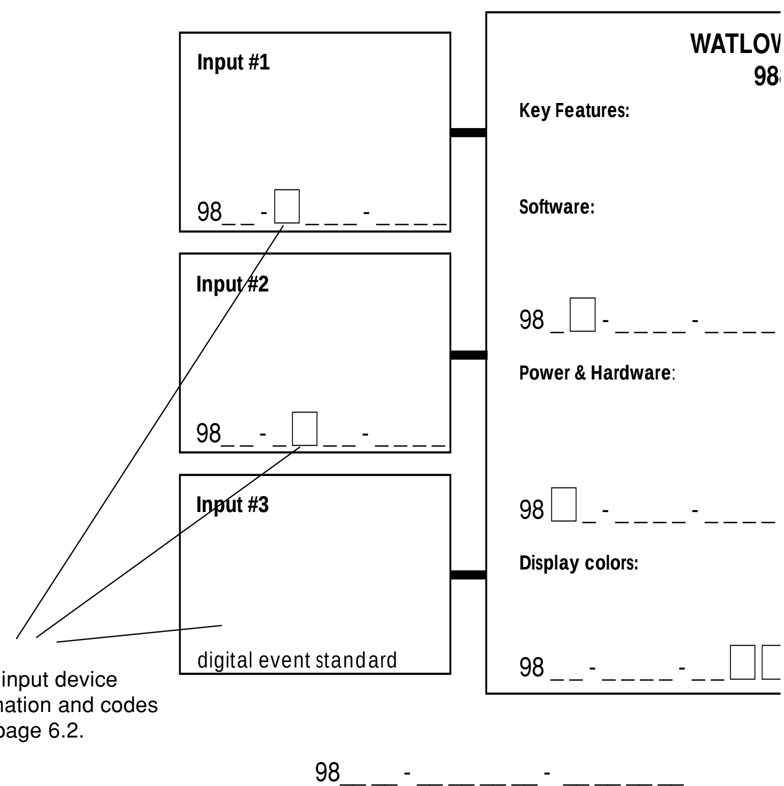
option available if shaded

A. List all the input devices in your process sketch (Refer to your answer to 1D.).

B. List all of the parameters and specifications that apply to each of the above items.

C. Input types must match the appropriate input of the 988. Use the input chart on page 6.2 to assign each input device to one of the 988's inputs.

D. Use the information on your list to fill out the input boxes in your photocopy of the worksheet from page 7.10.



Fill in input device information and codes from page 6.2.

How to Choose the Right 988 to Fit Your Application

Step 3: Output

HELPFUL REFERENCES

Use the complete output table in Chapter 6, Specifications.

Alarms and, transmitter power supply are explained in Chapter 5, Other Features.

See the filled in worksheets in Chapter 1, Test Drives.

	Outputs 1	2	3	4
A-none				
solid-state relay				
B-0.5A w RC suppression				
K-0.5A w/o RC suppression				
open collector				
C-switched DC				
electromechanical relay				
D-form C, 5A w RC supp				
E-form C, 5A w/o RC supp				
electromechanical relay				
J-form A or B, 5A w/o RC spp				
universal process types				
F-0-5VDC, 1-5VDC, 0-10VDC; 0-20mA, 4-20mA				
transmitter power supply				
T-5, 12, 20VDC @ 30 mA				
process retransmit				
M-0-20mA, 4-20mA				
N-0-5VDC, 1-5VDC, 0-10VDC				
communications				
R-RS-232				
S-EIA485, RS-422				

options available if shaded

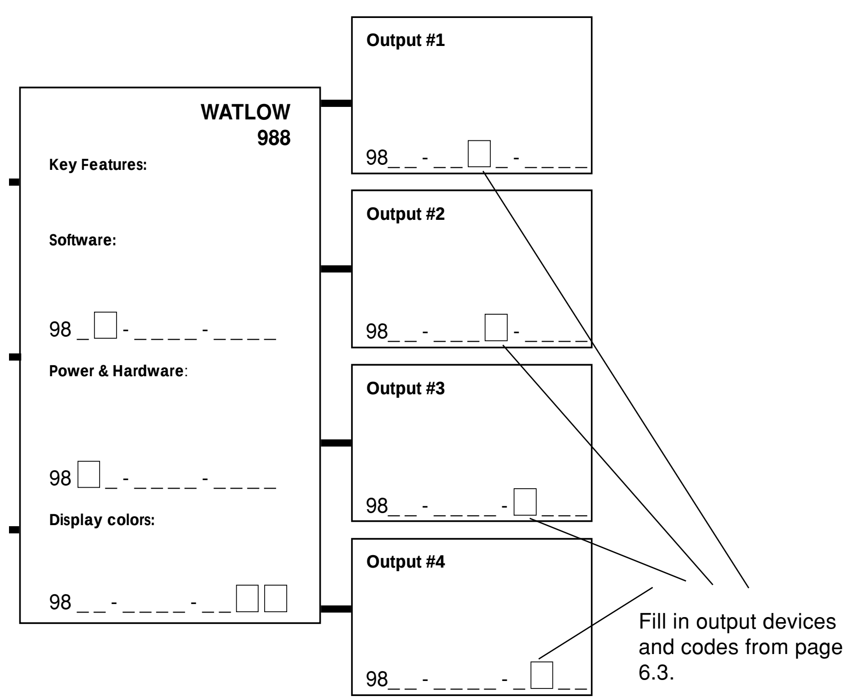
A. List all the output devices in your process sketch (Refer to your answer to 1F.).

B. List all of the parameters and specifications that apply to each of the above items.

C. Output types must match the appropriate output of the 988. Use the Output Chart on page 6.3 to assign each output device to one of the 988's outputs.

D. Use the information on your list to fill in the output boxes in your photocopy of the worksheet from page 7.10.

E. Make a sketch of your application on your photocopy of the worksheet. Make sure the appropriate devices are connected to the appropriate inputs and outputs.



Step 4: Software

HELPFUL REFERENCES

General Software Features

☐ auto-tune	3.2
☐ burst fire	3.3
☐ communications	3.4
☐ dead band	3.5
☐ digital event	3.6
☐ heater current	3.7
☐ input filter	3.8
☐ input linearization	3.9
☐ ramp to set point	3.10
☐ remote set point	3.11
☐ retransmit	3.12
☐ slidewire feedback	3.13

Enhanced Software Features

☐ cascade	4.2
☐ differential	4.4
☐ dual PID sets	4.5
☐ duplex	4.6
☐ ratio	4.7

See the filled in worksheets in Chapter 1, Test Drives.

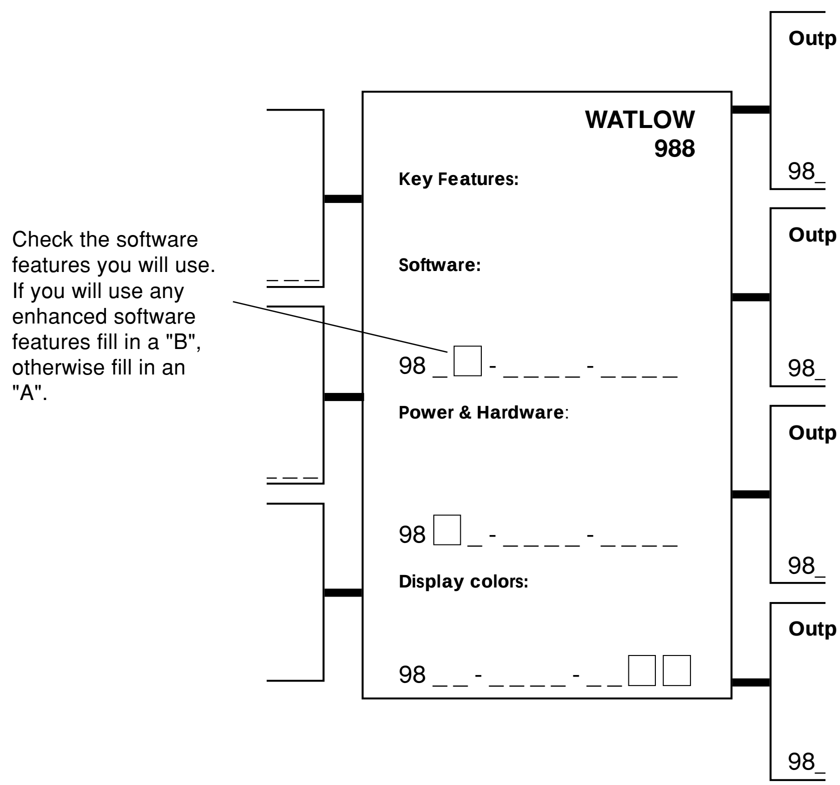
A. Determine what software features your process will require.

B. Determine the process range or ranges that the software must maintain in the process.

C. Determine what conditioning, if any, is needed for your input data.

D. Will you use any enhanced software features?

E. Use the information you have just gathered to fill in the software box in your photocopy of the worksheet from page 7.10.



Step 5: Standard Features

HELPFUL REFERENCES

☐ calibration	5.3
☐ diagnostics	5.4
☐ factory settings	5.5
☐ errors (input)	5.6
☐ lockout	5.7
☐ moisture resistance	5.8
☐ displays and keys	6.5
☐ setup	6.6
☐ isolation	6.7
☐ training	6.8
☐ manual	6.9
☐ spec chart	6.10
☐ warranty	6.11

A. This section lists features that may be important to your application that are built into all of the 988 family of controllers. None of this information is needed on your worksheet, but you might want to take some time to learn about these features.

calibration
diagnostics
factory settings
errors (input)
lockout
water- and corrision-resistant front panel
display and keys
setup
isolation
user's manual
product specifications
three-year limited warranty

Step 6: Hardware

HELPFUL REFERENCES

- ☐ lockout 5.7
- ☐ dimensions 6.4
- ☐ display & key chart 6.5
- ☐ specifications 6.8

	vertical	horizontal
100-240 V	988	989
24-28 V	986	987

A. Would the controller fit your applications panel better in its vertical configuration (986 or 988) or horizontal configuration (987 or 989)? Be sure to check all dimensions for fit.

B. Will you connect your controler to a 100- 240-volt power supply (988 or 989) or a 24-28-volt power supply (986 or 987)? (Either configuration works with either AC or DC power.)

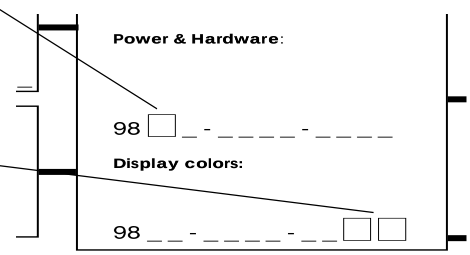
C. Each of the two displays in the 988 family can be either red (R) or green (G). Choose a color for each display.

D. You can lockout access to controller settings with software, hardware switches or with an digital event input. All of these are standard features.

E. Fill in the appropriate spaces in your photocopy of the worksheet from page 7.10. You should have all the information you need to fill in the part number.

Use the table to choose and fill in your power and hardware configuration.

Choose the upper and lower display colors.
RR - red upper, red lower
RG - red upper, green lower
GG - green upper, green lower
GR - green upper, red lower



Step 7: Review and Optimize

A. Review the last six steps looking for errors and opportunities to optimize your application's use of the Series 988 controller..

B. If any of the inputs or outputs are not used by your application, check whether they could be used to enhance your application, perhaps with the addition of an alarm or the communications option.

C. How might your needs change in the future? It's more efficient and economical to order options now.

D. Make several copies of the worksheet on the next page and "test drive" your application through different conditions. What happens if conditions exceed limits? What happens if a device breaks down?

E. Go over your work with a colleague and/or a Watlow sales rep to check whether you have overlooked anything.

F. If you made any changes on your worksheet, revise your model number.

HELPFUL REFERENCES

Chapter 1, Test Drives, provides diagrams and explanations of several different types of applications.

Chapter 2, Basic Control Strategies and Terms, explains the basic concepts and vocabulary of control applications.

Notes Page

Faxable Series 988 System Description

date:
# of pages:

to:
from:

comp/dept:
comp/dept:

phone:
phone:

fax:
fax:

Input #1

98_ _ - ☐ _ _ _ - _ _ _ _

Input #2

98_ _ - _ ☐ _ _ - _ _ _ _

Input #3

digital event standard

WATLOW 988

Key Features:

Software:

98 _ ☐ - _ _ _ _ - _ _ _ _

Power & Hardware:

98 ☐ _ - _ _ _ _ - _ _ _ _

Display colors:

98 _ _ - _ _ _ _ - _ _ ☐ ☐

Output #1

98_ _ - _ _ ☐ _ - _ _ _ _

Output #2

98_ _ - _ _ _ ☐ - _ _ _ _

Output #3

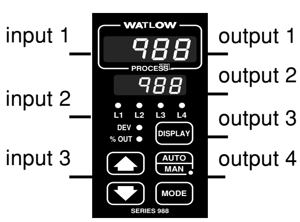
98_ _ - _ _ _ _ - ☐ _ _ _

Output #4

98_ _ - _ _ _ _ - _ ☐ _ _

98__ __ - __ __ __ __ - __ __ __ __

Sketch your application in this space.



Make photocopies of this page. Do not write on the original. Use the information you gathered in the previous pages to fill in the boxes and model number.

How to Choose the Right 988 to Fit Your Application

Series 988/989 Model Number Information

98 _ _ - _ _ _ _ - _ _ _ _

Hardware
6 = Vertical mounting, 24-28 V
7 = Horizontal mounting, 24-28 V
8 = Vertical mounting, 100-240 V
9 = Horizontal mounting, 100-240 V

Software
A = Standard
B = Enhanced (with cascade, ratio, dual PID, differential)

#1 Input
1 = Basic thermocouple signal conditioner (excluding Type R, S and B)
2 = Universal signal conditioner

#2 Input
0 = None
1 = Basic thermocouple signal conditioner (excluding Type R, S and B)
2 = Universal signal conditioner
3 = Slidewire feedback
4 = Current transformer
5 = Second digital event (one digital event is standard on all units)

#1 Output
B = Solid state relay, Form A, 0.5A, with RC suppression
C = Switched DC, open collector, isolated
D = *Electromechanical relay, Form C, 5A, with RC supression
E = *Electromechanical relay, Form C, 5A, without RC suppression
F = Universal process, 0-5VDC, 1-5VDC, 0-10VDC, 0-20mA, 4-20mA
K = Solid state relay, Form A, 0.5A, without RC suppression

#2 Output
A = None
B = Solid state relay, Form A, 0.5A, with RC suppression
C = Switched DC, open collector, isolated
D = *Electromechanical relay, Form C, 5A, with RC suppression
E = *Electromechanical relay, Form C, 5A, without RC suppression
F = Universal process, 0-5VDC, 1-5VDC, 0-10VDC, 0-20mA, 4-20mA
K = Solid state relay, Form A, 0.5A, without RC suppression
T = External signal conditioner power supply, 5, 12 or 20VDC @ 30mA

#3 Output
A = None
B = Solid state relay, Form A, 0.5A, with RC suppression
C = Switched DC, open collector, isolated
J = *Electromechanical relay, Form A or B, 5A, without RC suppression
K = Solid state relay, Form A, 0.5A, without RC suppression
M = Retransmit, 0-20mA, 4-20mA
N = Retransmit, 1-5VDC, 0-10VDC, 0-5VDC
T = External signal conditioner power supply, 5, 12 or 20VDC @ 30mA

#4 Output
A = None
B = Solid state relay, Form A, 0.5A, with RC suppression
C = Switched DC, open collector, isolated
D = *Electromechanical relay, Form C, 5A, with RC suppression
E = *Electromechanical relay, Form C, 5A, without RC suppression
K = Solid state relay, Form A, 0.5A, without RC suppression
R = Isolated RS-232 communications
S = Isolated EIA-485/RS-422 communications
T = External signal conditioner power supply, 5, 12 or 20VDC @ 30mA

Display Color (Upper/Lower)
GG = Green/Green
GR = Green/Red
RG = Red/Green
RR = Red/Red

*Electromechanical relays are not recommended for PID control. They are warranted for only 100,000 contact closures

Sensor Ranges

J t/c:	32	to	1500°F	
	0	to	816°C	
K t/c:	-328	to	2500°F	
	-200	to	1371°C	
T t/c:	-328	to	750°F	
	-200	to	399°C	
N t/c:	32	to	2372°F	
	0	to	1300°C	
R t/c:	32	to	3200°F	
	0	to	1760°C	
S t/c:	32	to	3200°F	
	0	to	1760°C	
B t/c:	1598	to	3300°F	
	870	to	1816°C	
E t/c:	-328	to	1470°F	
	-200	to	799°C	
C t/c:	32	to	4200°F	
	0	to	2316°C	
D t/c:	32	to	4200°F	
	0	to	2316°C	
Pt 2:	32	to	2543°F	
	0	to	1395°C	
100Ω platinum: 1°RTD (JIS):	-328	to	1166°F	
	-200	to	630°C	
100Ω platinum: 1°RTD (DIN):	-328	to	1472°F	
	-200	to	800°C	
100Ω platinum: 0.1°RTD (JIS and DIN):	-99.9	to	999.9°F	
	-73.3	to	537.7°C	
0-5VDC:	-999	to	9999	
1-5VDC:	-999	to	9999	
0-10VDC:	-999	to	9999	
0-20mA:	-999	to	9999	
4-20mA:	-999	to	9999	
0-50mVDC:	-999	to	9999	
0-100mVDC:	-999	to	9999	
Slidewire:	100	to	1200Ω	
Current:	0	to	50mA	
Potentiometer:	0	to	1200Ω	

Index

A

A/D overflow error 5.6
A/D underflow error 5.6
accuracy 6.8
actuator interfaces 2.6
address prompt 3.4
agency approvals 6.8
alarm 2 high 5.2
alarm 2 low 5.2
alarm high 3.10
alarm low 3.10
alarm reset 3.6
alarm silencing 1.5, 1.7
alarms 2.6, 5.2, 6.6
algorithm prompt 4.5
aluminum melting furnace 1.6
ambient counts 5.5
ambient temperature 2.6, 5.5
analog output 3.12
annunciation output 2.6
annunciator 2.8
auto mode 5.6
auto reset 2.4
auto-tune 1.3, 2.3, 3.2, 4.3, 4.5, 6.6
auto-tune prompt 3.2, 4.3
auto-tune set point 3.2
auto-tune set point parameter 4.3
auto-tuning 2.3, 4.5
AUTO/MAN key 3.2, 5.2, 5.3, 5.4, 5.6, 5.7, 6.5
AUTO/MAN LED 6.5
auto/manual 5.4
automatic mode 5.4
automatic reset 2.2, 2.4
automatic tuning 2.3

B

Barber Coleman 560 1.4
basic signal conditioner 6.2
baud rate 2.6, 3.4
boiler 4.4
break protection 2.10
bumpless transfer 5.4, 5.6
burst fire 2.6, 2.8, 3.3, 3.7
buzzer 5.3

C

calibration manual 2.7
Calibration menu 6.5
calibration offset 2.8
cascade 1.6, 1.7, 2.7, 2.8, 4.2
case 2.7
chart recorder 2.6, 3.12
chattering 2.2
closed loop 2.2, 2.8, 5.4
cold junction 2.8, 2.10
communications 2.6, 3.4, 6.3
Communications menu 3.4
compression molding press 3.7
computer 3.4
configuration error 5.6
configure 6.6
control mode 2.2, 6.8
control output action 3.6
control parameter 4.7
control prompt 4.4
control room 5.8
control software revision 5.5
control strategies 2.2
controller environment 2.6
controller operation 2.7
CSA 2.7, 6.8
current 3.7
current monitor 2.6, 5.5
current retransmit 5.5
current transformer 2.8

D

damping 2.4
data bits and parity 3.4
dead band 2.8, 3.5
decimal 2 3.11
decrement key 3.11, 4.4, 5.6, 6.5
default parameters 2.8
defects 6.9
derivative 2.3, 2.4, 2.8, 2.10, 3.2
derivative 1 5.2
derivative 2 5.2
Deutsche Industrial Norms 2.8
DEV (deviation) LED 6.5
deviation alarm 1.5, 2.6, 5.2, 5.3
device address 3.4
diagnostics 5.4, 5.5
Diagnostics menu 2.7, 5.5
differential 2.7, 2.8, 4.4
digital event 3.6, 5.7, 6.2
dimensions 2.6, 6.4
DIN 2.8
DIP switch 3.11, 5.7, 6.6, 6.7
display 5.5
DISPLAY key 3.7, 4.4, 6.5
display loop 6.5
displays 6.5, 7.8
documentation 6.6
down-arrow key, see decrement key
droop 2.2, 2.3, 2.4, 2.8
drying grain 1.4
dual PID 1.3, 4.5
duplex 2.8, 4.6
duty cycle 2.8

E

EIA-485/422 1.9, 2.6, 3.4, 5.5, 6.3
electrically noisy environment 5.8
electromechanical relays 6.3, 6.8
enclosure heater 2.7
enhanced software 3.2, 4.1-4.7, 7.6
environmental chamber 3.5, 3.8
error 2.7
error code 5.6
event input 2.7, 4.5
event input 1 prompt 3.6
event input 2 5.5, 5.7
external transmitter power supply 2.8
extruder 1.2

F

factory menu 5.7, 6.6
factory prompt 5.5, 5.7
failure mode prompt 5.6
field calibration 2.7
filter 2.8
filter time constant 3.8

Index

fixed power output 5.6
flow transmitter 1.8, 3.9
form A relay 2.8, 5.2, 6.3
form A/B relay 5.5
form B relay 2.8, 5.2, 6.3
form C relay 2.9, 5.2, 5.5, 6.3
four dashes 5.6
front panel 2.7
front panel lockout 3.6
full lockout 5.7

G

gas valve 5.6
gas-fired furnace 3.13
gaskets 2.7
Global menu
    3.6, 3.10, 4.4, 4.5, 4.7, 5.6, 5.7
ground counts 5.5
ground loops 2.5

H

hardware 7.8
heat-treat oven 3.12
heater current 1.2, 2.7, 3.3, 3.7
heater current transformer 6.2
horizontal version (989) 1.7, 7.8
hose-down 2.7
hunting 1.5, 2.9, 3.13
hysteresis 2.2, 2.9, 5.2

I

idle set point 3.6
idle temperature 3.6
increment key
    3.11, 4.4, 5.6, 6.5
incubator 3.6
input 1 counts 5.5
input 1 linearization 3.9
input 2 counts 5.5
input 2 linearization 3.9
input 2 prompt 3.7, 3.11, 3.13
input devices 7.4
input errors 5.6
input filter 3.8
input linearization 2.9, 3.9
Input menu 3.7, 3.11
Input Table 6.2
inputs 2.5, 5.5, 6.8
integral 2.2, 2.4, 2.9, 2.10, 3.2
integration function 2.3
interactive process variables 2.7
interface prompt 3.4
internal percent 4.3
internal set point 4.2, 4.4
isolation 2.9

J

JIS 2.9
Joint Industrial Standards 2.9

K

keylock switch 5.7
keys 6.5

L

latching alarm 2.6, 5.2
learn high resistance value 3.13
learn low resistance value 3.13
LED 5.4, 5.5, 6.5
limits 1.7, 2.5, 2.6
linearization 2.9
local 3.11
local-remote prompt 3.11
lockout 3.6, 5.7
long lag times 4.2
long sensor lead 5.8
loop error detect 3.7
louver 1.4, 1.5
low-level contact 1.9
low-pass filter 3.8
lower display 6.5

M

manual mode 5.4, 5.6
manual tuning 2.3
master-remote 2.6, 3.11
mechanical relays 2.6
MODE key
    3.6, 3.13, 5.5, 5.7, 6.5
model number 7.1
motorized valve 4.7
mounting 6.4, 6.6, 6.7
muffle furnace 3.10
multi-zone application 3.12

N

natural oscillation 2.4
NEMA 4X 2.7, 2.9, 6.8
no lockout 5.7
no module 5.5
noise immunity 2.5
non-latching alarm 2.6, 5.2
non-volatile checksum error 5.6
normally de-energized 5.2
normally energized 5.2

O

offset 2.4
ON/OFF control 2.2, 2.9
open collector 3.3, 6.3
open loop 2.2, 2.9, 5.4
open loop prompt 5.5
operating environment 6.8
operator interface 6.8
optimize 7.9
output 1 active 5.5
output 4 active 5.5
output devices 7.5
Output menu 3.12, 5.3
Output Table 6.3
outputs 2.5, 2.9, 5.5, 6.8
outputs, turn off 3.6
overshoot 2.3, 2.4, 2.9

P

P control 2.9
paint 4.7
panel cutouts 6.4
Panel Lockout menu 5.7
panel lockout prompt 5.5
part number 6.6
PD control 2.9
PDR control 2.7, 2.9
percent power output 5.4
percent power output (%OUT)
    LED 6.5
personal computer 2.6
PI control 2.9
PID 2.2, 2.3, 2.7, 2.9,
    2.10, 3.2, 4.2, 4.3, 4.5
PID A 4.3, 4.5
PID B 4.3, 4.5
PID menus 3.5
PLC 3.11
power 6.8, 7.7
power supply 5.5, 5.8, 7.8
pressure switch 4.5
process 2.2, 4.5, 5.5
process 1 5.2

Index

process 2 5.2
process 2 prompt 3.7
process alarms 2.6, 3.7, 5.2
process input 6.2
process retransmit 6.3
process variable 2.9
product specifications 6.8
proportional band 2.4, 2.9, 3.2
proportional control mode 5.5
proportional derivative control with manual reset 2.9
proportional-integral control 2.3
proportional-integral-derivative (PID) 2.3
proportioning control 2.2, 2.9, 2.10
proportioning control with derivative 2.9
protocol 3.4

Q

QCD 3.3
QPAC 3.3
questions and answers 2.5

R

radio frequency interference 1.7
radio frequency noise 3.3
ramp rate 3.10
ramp to set point 1.3, 2.7, 3.10
ramping function prompt 3.10
range 2.5
range high 2 3.11, 3.13, 4.3
range high 2 prompt 3.7
range low 2 3.11, 3.13
range low 2 prompt 3.7
rate 2.3, 2.4, 2.10, 5.2
rate alarm 3.10
rate band 2.9
ratio control 1.8, 1.9, 2.7, 2.9, 4.7
read only 5.7
reference junction 2.10
relative humidity 3.8
remote set point 3.6, 3.11, 4.4
reset 2.4, 2.10
resistance temperature detector (RTD) 2.5, 2.10, 6.2
retransmit 2.6, 2.10, 3.12
retransmit calibrate offset 3.12
retransmit high limit 3.12
retransmit low limit 3.12
retransmit options 3.11
RFI 3.3
RS-232 3.4, 5.5, 6.3
RS-422 1.9, 2.6, 3.4, 6.3
RTD 2.5, 2.10, 6.2

S

safety limits 2.6
SCR firing card 3.3
security 2.7, 5.7
semiconductor oven 3.3
sensor break 5.4, 6.8
sensor cost 2.5
sensor fails 5.6
sensor over-range error 5.6
sensor ranges 6.8
sensor under-range error 5.6
serial communications 3.4
serial number 5.5
serial port 3.4
Series 988/989 User's Manual 6.6, 6.7
set point 3.10, 4.5
setup 3.4, 6.6
Setup menu 5.6, 5.7, 6.5, 6.6
ship date 5.5
shipping overseas 2.7
signal transmitter 2.5
silencing alarm 2.6, 5.3
sketch 7.1-7.11
slidewire feedback 1.4, 2.7, 2.10, 3.13, 6.2, 5.5
slidewire valve actuators 3.13
software features 7.6
software revision 5.5
solid-state output 2.6
solid-state relay 3.3, 6.3
spacing between controllers 2.6
specifications 6.8
square root extraction 3.9
SSR firing card 3.3
standard features 5.1-5.8, 7.7
start 3.10
startup 2.7, 6.6
switch PID sets 3.6
switched DC 5.5
switching sensitivity 2.10
system cycle time 2.4
system diagram 2.5
System menu 3.11, 5.7
system response time 2.4
system stress 2.7
system tuning 2.3

T

terminals 6.8
test chamber 3.4, 4.5
test output prompt 5.5
thermal lag 2.3
thermal system 2.10
thermocouple 2.10, 6.2
thermocouple only 5.5
three-mode control 2.10
three-way valve 4.6
time proportioning control 2.2, 2.10
transmitter power supply 2.10, 6.3
tune 3.2
Tuning of Industrial Control Systems 2.4
tuning reference 2.4
tuning the system 2.4

U

UL 1.9, 2.7, 6.8
UL recognized 1.9
uncontrolled stream 4.7
universal millivolts 5.5
universal off 5.5
universal process types 5.5, 6.3
universal RTD 5.5
universal signal conditioner 3.9, 6.2
universal tc high gain 5.5
universal tc low gain 5.5
up-arrow key, see increment key
updates 2.5
upper display 6.5
urethane mixing 1.8
user's manual 6.7

V

vacuum 4.5
valve oscillations 3.13
variable-time-base 2.6, 2.8, 3.3
vertical configuration 7.8

Index

voltage retransmit 5.5

W

warranty 6.9
waste water process 3.9
wire length 2.5
wiring 6.6, 6.7

Z

zero-cross fired 1.7, 3.3
zero-cross switching 3.3
zero-switching 2.8, 2.10

Prompst, parameters and menus

232 RS-232 **5.5**
485 EIA-485/422 **5.5**

A

A2HI alarm 2 high **3.10, 5.2**
A2LO alarm 2 low **3.10, 5.2**
ACAL retransmit calibrate offset **3.12**
Acnt ambient counts **5.5**
Actn control action output **3.6**
Addr address **3.4**
AL2 alarm 2 energized **5.2**
AL2n alarm 2 de-energized **5.2**
ALgO algorithm **4.5**
ALr alarm reset **3.6**
Amb ambient temperature **5.5**
Aout analog output **3.12**
ArH retransmit high limit **3.12**
ArL retransmit low limit **3.12**
AtSP auto-tune set point **3.2, 4.3**
AUt auto-tune **3.2, 4.3**

B

bAUd baud rate **3.4**
bPLS bumpless transfer **5.6**
brSt burst fire **3.3**

C

cnt1 input 1 counts **5.5**
cnt2 input 2 counts **5.5**
CntL control **4.4, 4.7**
Com communications **3.4**
Curr current **3.7, 5.5**

D

dAtA data bits and parity **3.4**
dAtE date **5.5**
db A dead band A **3.5**
db b dead band B **3.5**
dc switched dc **5.5**
dE1 deviation 1 **5.2**
dE2 deviation 2 **5.2**
dEC2 decimal 2 **3.11**
dIAg diagnostics **5.5**
dIFF differential **4.4**

Index

dISP display test **5.5**

E
E1 1 error 1-1 **5.6**
E1 2 error 1-2 **5.6**
E1 3 error 1-3 **5.6**
E1 4 error 1-4 **5.6**
E2 1 error 2-1 **5.6**
E2 2 error 2-2 **5.6**
E2 3 error 2-3 **5.6**
E2 4 error 2-4 **5.6**
Ei1 event input 1 **3.6, 4.5, 5.7**
Ei2 event input 2 **4.5, 5.5, 5.7**
Er5 error 5 **5.6**
Er9 error 9 **5.6**

F
FAIL failure **5.6**
FctY factory **5.5, 5.7**
Ftr1 filter time constant 1 **3.8**
FULL full **5.7**

G
Gnd ground counts **5.5**

H
Hunt hunt **3.13**
HYS2 hysteresis **5.2**

I
IdSP idle set point **3.6**
In2 input 2 **3.7, 3.11, 3.13**
InPt input **3.7**
IntF communications interface **3.4**
IrEt current retransmit **5.5**
itY1 input 1 type **5.5**
itY2 input 2 type **5.5**

L
L local **3.11**
L-r local-remote **3.11**
LAt2 latching 2 **5.2**
Lin1 linearization 1 **3.9**
Lin2 linearization 2 **3.9**
LOC front panel lockout **3.6, 5.7**
LooP loop error detect **3.7**
LrnH learn high resistance **3.13**
LrnL learn low resistance **3.13**

N
nonE no module **5.5, 5.7**

O
OPLP open loop **5.5**
OtPt output **3.12**
OtY1 output 1 type **5.5**
OtY4 output 4 type **5.5**
out1 output 1 active **5.5**
out4 output 4 active **5.5**

P
Pid switch PID sets **3.6, 4.5**
Pid2 PID 2 **4.5**
PidA PID A **3.2, 4.3, 4.5**
Pidb PID B **4.3, 4.5**
PLOC panel lockout **5.5, 5.7**
Pr1 process 1 **5.2**
Pr2 process 2 **3.7, 5.2**
Prc1 process value 1 **3.12**
Proc process **4.5, 5.5**
Prot protocol **3.4**

R
r remote **3.11**
rAtE ramp rate **3.10**
rAtE rate **5.2**
rAti ratio **4.7**
rEAd read **5.7**
rH2 range high 2 **3.7, 3.11, 3.13**
rL2 range low 2 **3.7, 3.11, 3.13, 4.3**
rLAb relay A/B **5.5**
rLCS relay C surppress **5.5**
rLYC relay C **5.5**
root root extraction **3.9**
rP ramping **3.10**
rSP remote set point **3.6, 3.11**

S
SEt setup **3.4, 4.5, 5.7**
SIL2 silencing 2 **5.3**
SLid slidewire **3.13, 5.5**
Sn-- serial number upper **5.5**
---- serial number lower **5.5**
---- error output **5.6**
SOFt software **5.5**
SPLY power supply **5.5**
SSIS solid state 0.5A surppress **5.5**
SSr1 solid state 0.5A **5.5**
SSr2 solid state 2A **5.5**
StPt set point **3.10, 4.5**
Strt start **3.10**

T
tc thermocouple only **5.5**
tout test output **5.5**
tunE tune **3.2**

U
UmV universal millivolts **5.5**
UOFF universal OFF **5.5**
UPrc universal process **5.5**
UrEt voltage retransmit **5.5**
Urtd universal RTD **5.5**
Utch universal tc high **5.5**
Utcl universal tc low **5.5**

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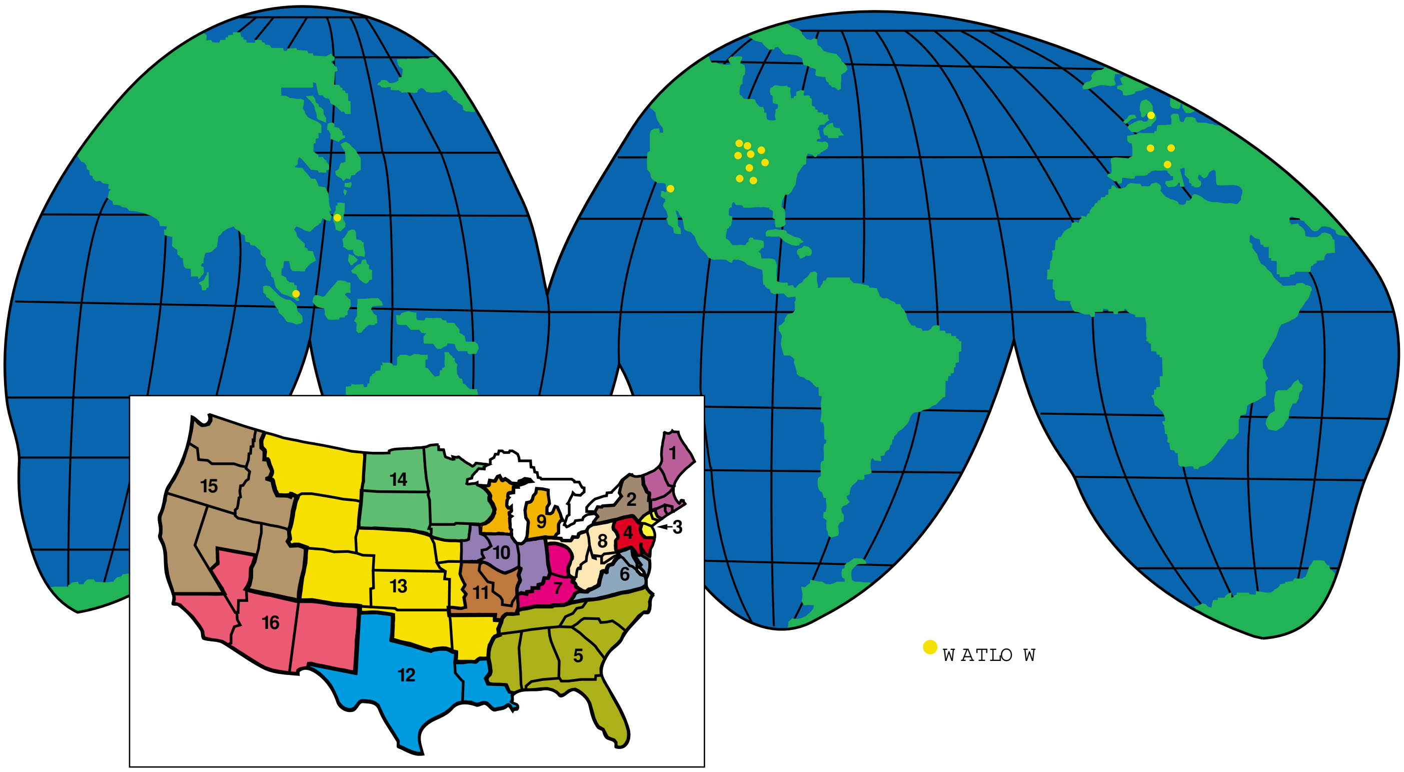

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